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Physiology Class-Book

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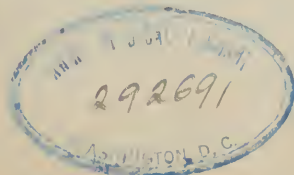
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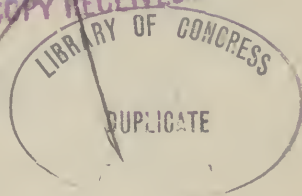


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PREFACE.

The Physiology Class-Book is the outgrowth of an attempt to combine the "text-book" and "lecture" methods of teaching Physiology. It was published first in 1895 for the use of students in the Warrensburg, Mo., State Normal School. The cordial endorsement of the plan of the book by those not associated with the Normal School suggested a broader field of usefulness than was at first contemplated. In revising the former edition the quantity of subject matter has been increased, the original plan of note taking modified, and references, by page numbers, to other books supplied. These changes have been made with a view of adapting it to the needs of those schools where there is a desire to study Physiology from the standpoint of a science, but where the school equipment, or the time of the teacher, does not permit of individual laboratory practice. The following statements, taken from the preface of the Class-Book as first published, explain its plan and purpose:

"Recognizing the pedagogical principle that to tell a pupil what he can easily find out for himself deprives him of an opportunity to think, while withholding from him what he cannot find out, wastes his time in useless endeavor, the aim has been to state in clear, concise English what the pupil *must be told* about the subject. This information is intended to serve as a basis for the *recitation*, and is to be supplemented by text-book references, lectures, experiments, observations, and illustrative drawings. The blank spaces are for the recording of experiments, observations, etc., by the pupil, so that the completed book may contain his own work as well as the subject matter furnished him.

"Throughout, the subject has been treated from the standpoint of a natural science. Enough has been said and written of late upon

this view of Physiology to make a restatement of argument unnecessary here. Such a treatment, however, necessitates a clear statement of the principles underlying the science, and a logical arrangement of the parts, based, if possible, upon some central underlying truth. The central idea in the science of Physiology is *Nature's plan of maintaining life*. For this one purpose all the different parts of the human organism are made, directly or indirectly, to serve. The aim has been to arrange the parts of the subject in such an order that each successive step in the study will reveal more and more of this plan to the pupil.

"Further, in teaching a subject as a science, the appeal must be made to the pupil's reasoning powers rather than to his memory, and sufficient experimental and observational work must be done to furnish clear conceptions—the necessary basis for correct thinking. Physiology work should be supplemented by laboratory practice. Where this cannot be arranged for, class experiments and observations should be furnished by the teacher. The experiments and observations given in this book are intended for class purposes. The list is suggestive, rather than exhaustive, and contains such as require little apparatus."

The texts* to which references are made by page numbers, with the exception of Stowell's Essentials of Health (Missouri's State Text in current use) have an experimental basis, though they differ widely in the plan of presenting the subject. For the purposes of the school room it was thought best to make exhaustive reference to a few reliable texts, rather than occasional reference to a larger number.

The necessity of keeping such a book small enough for class purposes accounts for the omission of considerable material found in books of similar nature. Still, it is believed that the principles underlying the science of Physiology have been stated and the method suggested for mastering them.

WARRENSBURG, MO., Aug. 30, 1898.

*Foster and Shore's Physiology for Beginners, McMillan & Co.; Coltons' Experimental and Descriptive Physiology, D. C. Heath & Co.; and Jenkins' Advanced Lessons in Human Physiology, Indiana School Book Co.

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CHAPTER I.

General Structure and Function of the Body.

A Study of Tissues. The first step toward understanding our bodies will be to find out what materials or *tissues* form them. This can easily be done by dissecting and examining a portion of the body of some animal whose tissues are like our own.

Observation. Procure the leg of some small animal, such as a cat, rabbit, frog, or chicken. On the outside observe the *epidermal* tissue in the form of cuticle and hair, claws, scales or feathers, according to the specimen. With a sharp knife lay open the skin and observe that it is attached to the parts underneath by *connective* tissue. Next observe the amount and arrangement of the *muscular* tissue. With a blunt instrument separate the muscles by tearing apart the connective tissue sheaths, and find tough strips of connective tissue (the tendons) which attach the muscles to the bones. Find near the central part of the leg some white glistening cords (nerves) which form one variety of *nervous* tissue. At the ends of the bones (*osseous* tissue) find a layer of *cartilaginous* tissue. The *adipose* or fatty tissue is found immediately beneath the skin and in between the other tissues.

Fill in the following blank spaces with notes taken while observing the specimen :

1. Give the position, kind, and uses of epidermal tissue.

2. Position and appearance of adipose tissue.

3. Arrangement, appearance, use, and amount of muscular tissue.

4. Position, appearance, kinds, and uses of connective tissue.

5. Position, appearance, and uses of osseous tissue.

6. Position, appearance, and uses of cartilaginous tissue.

7. Appearance and position of nervous tissue.

What are Tissues? Tissues are the different kinds of material which form the body. These are to the body what the wood, stone, plaster, and other building materials are to a house. As a house is constructed from these different building materials, so the body is built up from the tissues. Hence tissues may be called *the building materials of the body*.

Kinds of Tissues. In the observation of the specimen the following tissues should be found:

1. Epidermal tissue (three varieties.) 2. Connective tissue (two varieties.) 3. Adipose or fatty tissue. 4. Muscular tissue (striated variety.) 5. Osseous tissue. 6. Cartilaginous tissue. 7. Nervous tissue (fibrous variety.)

The above named tissues form the greater portion of the body. Others less abundant but of considerable importance are: 8. Nerve cell tissue. 9. Non-striated muscular tissue. 10. Epithelial tissue.

Properties and Uses of Tissues. Each tissue in the body, like each kind of material in a house, is made to serve some definite purpose. It is able to serve this purpose because of its properties.

By the properties of a substance are meant its distinguishing qualities or characteristics. We recognize glass by its hardness, brittleness, and transparency. Hardness, brittleness, and transparency are therefore properties of glass. In some work on Physics, ascertain the distinction between the *general* and *special* properties of a substance and find a description of the property of *elasticity*.

While each tissue in the body has quite a number of properties of minor importance, it also has one or more properties of great importance in adapting it to some particular purpose in the body.

Important Properties of Tissues. 1. Of osseous tissue, *hardness*, *toughness*, and *stiffness*. 2. Of muscular tissue, *contractility*. 3. Of nervous tissue, *irritability*. 4. Of cartilaginous tissue, *stiffness* and *elasticity*. 5. Of connective tissue, *toughness* and *pliability*. 6. Of epidermal and epithelial tissues, *toughness* and resistance to the action of external agents.—Note that the properties named adapt each tissue to some special purpose in the body.

General Purposes of Tissues. 1. *Supporting tissues*—those which preserve the general form of the body and join the different parts together. Name them.

2. *Active tissues*—those capable of acting on the other tissues either to move or to control them. Name these.

3. *Protective tissues*—those which protect the more delicate parts of the body. What are they?

4. *Storage tissues*—those which store away material for future use. There is but one storage tissue of importance in the body. What is it?

Composition of Tissues. The tissues are made up principally of minute particles called cells. These are, for the most part, too small to be seen with the naked eye. In the body they vary in size from 1-4000 to 1-500 of an inch in diameter. They also vary in shape and general properties to suit their places in the body. A tissue is simply a collection of similar cells joined together, while the properties of a tissue are given to it by its cells. In addition to the cells peculiar to a given tissue, there is generally found between the

cells more or less of a substance without apparent structure. This is called *intercellular* material.

Observation. Examine with a compound microscope (1) some of the scrapings made from the inside of the cheek with a dull knife and (2) some thin slices cut from cartilage with a razor.

Plant cells may be seen by examining thin slices of elder pith, potato, and the stems of growing plants. Make drawings of the cells thus observed.

The Parts of a Typical Cell are known as the *cell wall*, the *protoplasm*, and the *nucleus*.

Draw a typical cell,
naming the parts.

Draw different forms
of cells. See S., 12.

Properties and Uses of Parts. The *cell wall* is supposed to be formed by the hardening of the outside of the protoplasm. It covers and protects the more delicate parts of the cell. The *protoplasm* resembles in appearance the white of a raw egg. It is capable of slight motion and is sensitive. It is able to absorb and appropriate liquid food, and to grow. It is the living, active portion of the cell and is the one part which is absolutely essential. The other parts may be absent from the cell but never the protoplasm. Through the protoplasm of many cells is scattered more or less of granular matter, the function of which is unknown. The *nucleus* differs from the protoplasm in being denser and clearer. Its function is not fully understood, but it is supposed to give the cell the power of forming new cells. Cells from which the nuclei are absent are unable to form new ones.

Conditions Surrounding the Cells. Although the cells are packed very closely together in the tissues, there is still room for a

quiet, colorless liquid to find its way freely among them. This liquid is called the *lymph*. It contains such food materials as the cells need for their growth and repair which it exchanges for materials thrown off from the cells as waste. The lymph in turn is supplied with necessary materials and relieved of waste by a second liquid, the *blood*, which flows through a system of tubes which penetrate the tissues in all directions.

Activities Within the Cells. In order that the cell may live, grow, and carry on its work in the tissue, it is necessary that certain activities be kept up within it. From the surrounding liquids the cell absorbs an active element called *oxygen* and a number of substances dissolved in water, making a kind of *liquid food*. Within the cell the oxygen unites with certain portions of the liquid food and with the protoplasm of the cell. As a result of these unions, heat and force are liberated, waste matter formed, and new material produced. The heat keeps up the necessary warmth of the cell; the force enables it to carry on its work; the new material is added to the protoplasm; and the waste matter flows out into the lymph.

These activities are therefore of four distinct kinds:

1. *Absorption*, whereby new materials are taken into the cell from the outside.
2. *Chemical change*, caused by the uniting of oxygen with substances in the cell and resulting in the production of heat, new material, and waste material.
3. *Addition* of the new material to the protoplasm of the cell, causing it to grow.
4. *Excretion*, or the throwing off of waste material.

Formation of New Cells. In all the tissues there occurs, at some stage of the growth of the body, the process of cell formation, or reproduction. In a few tissues, the epidermal for example, this process takes place continuously during life in order to supply new cells for replacing old and worn out ones. New cells are *always* formed from old ones. The most common plan by which this is accomplished is called *cell division*. By this plan a single cell will, after attaining its growth, separate into two or more new cells. The new cells thus formed begin at once to grow, absorbing liquid food and oxygen and may, upon attaining their full size, divide to form other new cells.

1.

2.

Make drawings to show different stages in cell division.

Importance of the Cells. A knowledge of the structure, growth, and work of cells is the first step toward a clear understanding of the body. The body grows by the growth and reproduction of its cells. All of its work is done by them. It is nourished and kept alive by nourishing and keeping alive the cells which compose it. The cell is thus the unit of structure and of function.

Organs and Systems. Any part of the body which has some special work to perform is called an *organ*. The eye is the organ of sight. The hand is an organ for grasping. Name other examples. What different tissues are found in the hand? What purpose does each tissue in the hand serve?

A collection of organs working to accomplish the same end or purpose in the body is called a *system*. The heart, arteries, veins, and capillaries, for example, have for their common purpose the circulation of blood and together they form the circulatory system. Name the organs which form the digestive system.

The Plan of the Body. Viewed externally, the body is seen to be made up of a central portion, the trunk, to which is attached the head, the upper extremities (arms and hands), and lower extremities (legs and feet).

The internal structure is adapted in various ways to the peculiar needs of the body. The plan here provides for: (1.) A framework or skeleton to which the other



Complete the sketch, showing and naming the important cavities of the body.

parts are attached. (2) The motion of the body as a whole and of its parts. (3.) Cavities for holding important organs. (4.) A continuous supply of liquid food and oxygen and the removal of waste material from all parts of the body. (5.) A supply of heat for warming the body and of force for carrying on its work. (6.) The intelligent oversight and general management of the body and the control of each part. (7.) Protection of the body as a whole and of its parts.

The Maintenance of Life. Notwithstanding the great variety of work carried on by the different portions of the body, all parts of it must be regarded as working for one purpose, which is the *maintenance of life*. In one sense the body may be regarded as a mechanism whose purpose is the maintenance of life. The relation of the different organs and systems to each other, and to the body, as a whole, is therefore such that each is made to contribute something directly or indirectly toward this end.

While the nature of life is, as yet, a great mystery, the plan of maintaining it in the bodies of animals is fairly well understood. Physiologically speaking, the life of the body may be regarded as the sum of the lives of the cells which compose it. Hence all effort toward maintaining life must be directed toward the cells.

Anatomy, Physiology, and Hygiene are terms which designate the different standpoints from which the body may be studied.

Anatomy treats of the construction of the body—the parts which compose it, what they are like, and where they are located. It is of two kinds, known as Gross Anatomy and Histology. Gross Anatomy is the study of rough, coarse structures—those parts which can be seen readily by the naked eye. Histology is the study of the minute structures—those parts which are too small to be seen by the naked eye and which can be known only by the use of the microscope.

Physiology treats of the function or use of the different parts of the body, the work which these parts do, and how they do it, and the relation they sustain to each other in the maintenance of life.

Hygiene treats of the ways of taking care of the body and keep-

ing its parts in good working order. The conditions which must be observed in doing this are termed the "laws of health." All the laws of health may be summed up in one fundamental law, which is this:

Habits of living must be in harmony with the plan of the body.

References.* On cells, S., 11-16; J., 29-34; C., 6. On tissues, J., 23-27; F. and S., 1. On systems, J. 28.

Practical Questions. 1. Compare the tissues of the body to the building materials of a house. 2. Show that the use made of building materials in both house and body must depend upon their properties. 3. If a tissue be compared to a brick wall, to what do the separate bricks correspond? To what, the mortar between the bricks? 4. What relation do cells, tissues, organs, and systems sustain to each other in the construction of the body? 5. Compare the conditions surrounding a one-celled animal living in water to the conditions surrounding the cells within a tissue. 6. Describe the different activities taking place within the cell. 7. What results are brought about by the uniting of oxygen with material in the cells? 8. Why is protoplasm regarded as the most important part of the cell? 9. Define and illustrate general use of the terms, structure, function, composition, and property.

*In references the initial of the author's name only is given. J. indicates Jenkins' Advanced Lessons in Human Physiology; S. Stowell's Essentials of Health; C. Colton's Experimental and Descriptive Physiology; and F. and S. Foster and Shore's Physiology for Beginners.

CHAPTER II.

The Blood.

Two Liquids of similar nature are found in the body, known as the blood, and the lymph. The former is kept moving rapidly through a system of tubes called the blood vessels, while the latter is allowed to lie in minute spaces in the intercellular material and to flow slowly through a second system of tubes called the lymphatics. Both liquids minister to the wants of the cells. The study of the lymph will be deferred to a later period.

A Study of Blood.

Secure through the assistance of a butcher (See Appendix) a bottle of blood which has been allowed to coagulate without shaking or stirring; a bottle of defibrinated blood; and a bottle of blood which has been kept from coagulating by mixing with Epsom salts.

Experiment. Let some of the defibrinated blood flow (not fall) on the surface of water in a glass vessel. Does it remain on the surface or sink to the bottom of the vessel?

Result.

Inference.

Experiment. Place a small amount of the dark, defibrinated blood in a large test tube or bottle and thin it by adding an equal amount of water. Then place the hand over the mouth of the tube and shake until the blood is thoroughly mixed with the oxygen of the air in the vessel. Compare with a portion of the blood not mixed with oxygen and notice any difference in color.

Result.

Inference.

Experiment in Coagulation. Fill four tumblers each two-thirds full of water. At intervals of one-half hour pour into each, and, thoroughly mix with the water, two tablespoonfuls of the blood containing the Epsom salts. The water dilutes the salts so that coagulation is no longer prevented. Jar the vessels occasionally as coagulation proceeds. After blood has been added to the tumbler make a comparative study of all. Sketch the tumblers showing the appearance of the blood in the different stages of coagulation.

1

2

3

4

Observation. Examine the coagulated blood in the bottle obtained from the butcher. Observe the dark central mass (the *clot*) surrounded by a clear liquid (the *serum*). Sketch the vessel and its contents, showing and naming the two parts into which the blood separates by coagulation.

Collection of Fibrin. Place the clot from one of the tumblers in which blood was allowed to coagulate into a large vessel of water. Thoroughly wash, adding fresh water until a clear, white, stringy solid remains. This substance is called *fibrin*.

Physical Properties of Blood.

The foregoing and other experiments show the blood to be heavier and denser than water; to have a faint odor and a slightly sweetish taste; to have a bright red color when it contains oxygen and a dark red color when oxygen is absent; and, when exposed to certain conditions, to undergo a change called coagulation.

The cause of coagulation is the fibrin. This substance does not exist in blood in its natural condition, but forms as coagulation takes place. It is formed from liquid substances, which are always present

in the blood, known as *fibrin factors*. Coagulation is therefore brought about by the changing of fibrin factors to fibrin. This generally occurs on the exposure of the blood to some unnatural condition, such as its escape from the blood vessels.

The Purpose of Coagulation is to check the flow of blood from wounds. Clots forming in the mouths of small blood vessels, when they are cut or broken, close them up and stop the flow of blood which would otherwise go on indefinitely.

Composition of the Blood. The blood is made up of two distinct portions, the *plasma* and the *corpuscles*. The plasma is a liquid. The corpuscles are small, round bodies, which float in the plasma. The corpuscles are of two kinds, the *red* and the *white*.

Observation. Examine with a compound microscope a small drop of human blood. (See Appendix.) This should be diluted with a little water or saliva, else the corpuscles will be too numerous to be distinguishable. Generally the only corpuscles to be seen are the red ones. Sometimes, however, the white ones may be found. They are easily distinguished from the red ones by their greater size and the peculiar way that light shines through them. On account of the small amount of coloring matter in a red corpuscle it does not appear red under the microscope.

Make a sketch of the corpuscles as they appear under the microscope.

Structure and Function of Red Corpuscles. The red corpuscle may be regarded as a single cell, though it has no nucleus and is supposed to be without a cell wall. It consists of a little mass of elastic and somewhat spongy protoplasm called the *stroma* which is saturated with a reddish coloring matter called *haemoglobin*.

In shape the red corpuscles are thin, circular disks with concave sides. In size they are about $\frac{1}{3300}$ of an inch through the long diameter and $\frac{1}{6500}$ of an inch through the short diameter. They are exceedingly numerous, there being estimated to be as many as five million in a small drop of healthy blood. In poor health, however, the number is greatly diminished.

The *function* of the red corpuscles is to act as *oxygen carriers*. They absorb oxygen from the air at the lungs and give it up to the

different tissues of the body. They owe this power entirely to the presence of the

Haemoglobin. This substance has the remarkable property of forming a weak chemical union with oxygen and, after being united with it for awhile, of giving it up to tissues which need oxygen. It forms about 9-10 of the solid portion of the red corpuscles and gives them their color. The stroma seems to be a contrivance for holding the haemoglobin.

Experiment. Procure a strong magnet, a weak magnet (a knife blade magnetized on strong magnet will serve), and some iron filings. Lay the strong magnet on a table a foot or two from a small pile of the iron filings. Pass the weak magnet first to the filings and then near the strong magnet, noting the effect. Repeat until convinced that all the filings may be transferred to the large magnet by the weak magnet acting as a carrier.

Apply to the action of the haemoglobin of the red corpuscle.

Origin of Red Corpuscles. As the red corpuscles are constantly being destroyed in various ways, new ones have to be regularly supplied from some source to take their place. Their origin is not definitely known, though the best authorities now agree that a portion of them, at least, is formed in the red marrow of the bones. There is also evidence to the effect that some of them may be formed in the spleen.

The White Corpuscles are irregular in shape and about three times as large as the red ones. They are much less numerous, there being in healthy blood only one white corpuscle for about every 300 red corpuscles. They are, for that reason, not easily observed in the blood. They may be obtained in large quantities from lymphatic glands.

Observation. Obtain from a butcher shop a small piece of the neck sweetbread of a calf. Press it between the fingers to squeeze out a whitish, semi-liquid substance. Dilute this with water on a glass slide and examine with compound microscope. Numerous white corpuscles, of different kinds, will be found. Make sketches of them. If a little dilute acetic acid be allowed to flow under the coverglass, the corpuscles will be rendered more transparent and the nuclei will become more distinct.

Sketch of white corpuscles.

The white corpuscles are endowed to some extent with the power of motion and are able to change their shape. For these reasons they are migratory in the body, being able to penetrate the thin walls of small blood vessels and to pass in between the cells. They collect in large numbers at parts of the body that may be inflamed and form a considerable portion of the white matter found in sores, called pus. They originate in lymphatic glands.

Sketch, showing the changes which a single white corpuscle may undergo in a few minutes.

The Function of White Corpuscles is not understood. Since there are different kinds of them in the blood, it is supposed that they serve different purposes. The two following uses are ascribed to them by most physiologists:

1. They help to keep the blood pure. They do this by destroying minute living bodies known as bacteria or disease germs which find their way into the blood.

2. They furnish a kind of ferment which causes the fibrin factors to change into fibrin in the coagulation of the blood. The ferment is given up on account of the injury which the corpuscles sustain by the escape of blood from the body.

The Plasma is the liquid portion of the blood. It consists of water with a great number of different substances dissolved in it and is prepared for the blood by the digestive organs. It is a very complex liquid. The following important constituents may be named:

1. The *fibrin factors* which, by changing into fibrin, cause the blood to coagulate.
2. Substances which serve as *food* for the cells. Chief among these are *serum albumen*, *fatty* substances, *sugary* substances, and *salts*.
3. *Impurities* from the cells, most important of which, are *carbon dioxid* and *urea*.

The *serum* is that portion of the plasma which remains, after the separation of the fibrin factors. When does this separation occur?

Functions of the Plasma. The plasma serves three main purposes: 1. It floats the corpuscles through the different blood vessels. 2. It supplies liquid food to the cells. 3. It serves as a carrier of impurities from the cells to the organs of excretion.

Changes in the Blood. In performing its work in the body, the blood must of necessity undergo rapid and continuous change. The following table indicates some of these changes and shows in a general way how they are accomplished:

	Supplied by.	Removed by.
Food substances.	The Digestive Organs.	The Cells.
Oxygen.	The Lungs.	The Cells.
Water.	The Digestive Organs. The Cells.	The Organs of Excretion. The Cells.
Impurities.	The Cells.	The Organs of Excretion.

In health there is such an adequate control of the supply of materials to the blood and of the removal of materials from the blood that its general composition and density do not change from time to time. An excess of certain impurities prompts a greater activity of the organs of excretion. If the blood becomes too dense, a feeling of thirst prompts one to drink water to thin the blood. Likewise a scarcity of food material causes a feeling of hunger, and a lack of

oxygen in the blood induces a desire for a deep breath of air. In time of fasting the blood obtains food materials from the tissues. Even the *quantity of blood*, which is about 1-1.3 of the entire weight of the body, remains nearly constant during the varying conditions of food and water supply and activity of the body.

Hygiene of the Blood. The condition of the blood is a most important factor in the general health of the body. An adequate supply of healthy blood is not only a safeguard against disease, but is a most important agent in the recovery of the body from the effects of disease. Moreover, the condition of the blood is largely dependent on one's habits of living. From a health standpoint, the most important constituents of the blood are the red corpuscles. These are generally sufficient in number and vigor in the blood of those who take plenty of physical exercise, expose the body freely to outdoor air and sunlight, and indulge in plenty of sleep. On the other hand they are always deficient in quantity and of inferior quality in those who pursue the opposite course. Impurities frequently find their way into the blood through the digestive organs. One should eat wholesome, well-cooked food, drink pure water, and limit the quantity of his food to what he can properly digest. The natural purifiers of the blood are the organs of excretion. The skin is one of these and its power to throw off impurities is proportional to its cleanliness, and the activity of the circulation of the blood through it. Alcoholic drinks have an injurious effect on the blood and interfere with its work in the body.

Patent medicines for purifying the blood, as a rule, do more harm than good. One may safely rely on wholesome food, pure water, outdoor exercise, sunlight, plenty of sleep, and a clean skin for keeping his blood in a good condition. When these natural remedies fail, let him consult a physician.

References. On description of blood, S., 93-99; J., 81-88; C., 94-98; F. and S., 26-31. On blood of lower animals, S., 100-101; J., 87; C., 51. On effect of alcohol on the blood, S., 102; C., 94.

Practical Questions. 1. State the necessity for a liquid like the blood in the body. 2. Show how its physical properties and composition adapt it to its different purposes. 3. Compare blood and water with reference to weight, density, complexity of composition, color, and odor. 4. Show how the blood, though a liquid constantly changing, is kept about the same in quantity, density, and composition. 5. Compare the red and white corpuscles with reference to

size, shape, number, origin, and function. 6. After coagulation, what portions of the blood are found in the clot? What portions in the serum? 7. What purposes are served by the water in the blood? 8. As a rule the blood of small animals coagulates more quickly than that of large animals. What is the necessity for this difference? 9. Account for the change of blood from a dark red to a light red color as it flows through the lungs. 10. If haemoglobin had a strong attraction for oxygen could it serve as a carrier of oxygen in the blood? Why? 11. What habits of living favor the development of red corpuscles? 12. Why will keeping the skin clean and active improve the quality of one's blood?

CHAPTER III.

Circulation of the Blood.

The blood is a *moving* liquid. Its regular movement through the body—starting at one place, flowing out to the different parts and returning to that place—is termed its circulation.

The Discovery of the Circulation of the Blood was made in 1616 by an English physician named Harvey. In 1619 he taught it in his public lectures and in 1628 published the proofs. No single discovery with reference to the human body has proved of so great importance. A knowledge of the nature and purpose of the circulation was the necessary first step in understanding the plan of the body and the method of maintaining life. Hence, Physiology as a science dates from the time of Harvey's discovery.

The Necessity for the Circulation lies in the fact that the blood acts as a *carrier* for the cells. Oxygen from the lungs, and liquid food from the digestive organs, reach the cells through the blood. Likewise, the blood must convey the impurities from the cells to the organs of excretion. To accomplish these results, *the blood must move*. So great is the necessity for the circulation that its stoppage, for only a brief interval of time, results in death.

The Organs of Circulation consist of a central force pump connected with a system of tubes which penetrate to all parts of the body. The force pump is called the *heart*, the tubes are called *blood vessels*. The blood vessels are of three kinds known as the *arteries*, the *veins*, and the *capillaries*.

The different organs of circulation are so connected that the blood flows through them in regular order. From the heart it flows

into the arteries; from the arteries into the capillaries; from the capillaries into the veins; and from the veins back into the heart.

Observation on the Heart. Procure, by the assistance of a butcher, the heart of a sheep, calf, or hog. To insure the specimen against mutilation, the lungs and diaphragm must be left attached to the heart. In studying the different parts, good results will be obtained by observing the following order:

1. Observe the connection of the heart to the lungs, diaphragm, and large blood vessels. Inflate the lungs and observe the position of the heart with reference to them.

2. Examine the sack surrounding the heart. It is called the *pericardium*. Pierce its lower portion and collect the pericardial fluid. Increase the opening thus made until it is large enough to slip the heart out through it. Slide back the pericardium until its attachment to the large blood vessels above the heart is found? Observe that a thin layer of it continues down from this attachment, making the outer covering of the heart.

3. Trace out for a short distance and study the veins and arteries connected with the heart. The arteries are to be distinguished by their thick walls. Carefully remove and save for later study a section each of an artery and vein, three or four inches in length. The heart may now be severed from the lungs by cutting the large blood vessels, care being taken to leave a considerable length of each one attached to the heart.

4. Observe the outer portion of heart. The thick lower portion contains the cavities called *ventricles*; the thin upper ear-shaped portions are the *auricles*. The thicker and denser side lies toward the left of the animal's body and is called the *left* side of the heart; the other is the *right* side. Locate the right auricle and the right ventricle; the left auricle and the left ventricle.

5. Make an incision into the right auricle large enough to see the inner portion. Observe the muscular arrangement and inner surface. At the entrance into right ventricle find the *tricuspid* valve.

6. Lay open the right ventricle. Study the tricuspid valve from the under side, noting its parts and the slender strips of connective tissue which attach the edges of the valves to muscular pillars in the ventricle. Study muscular arrangement and lining of the ventricle. Compare thickness of walls with those of right auricle. Find the opening into pulmonary artery.

7. Split open this artery to where it enters the ventricle and find the *right semi-lunar valve*. Of how many parts is it composed?

8. In like manner dissect the left side of heart. Compare the auricle, ventricle, and valves, on this side, with similar parts on the right side of heart.

9. Separate the aorta from the other blood vessels and cut it entirely free from the heart, care being taken to leave enough of the heart attached to the artery to insure the semi-lunar valves being left in good condition. After closing up the openings in the sides of the aorta, pour water into the small end and observe the closing of the semi-lunar valve. Repeat the experiment until the action of the valve is understood. Sketch the artery showing the valve in a closed condition.

Observations on the Heart of a

Position with reference to lungs.

Attachments.

Description of pericardium.

Size, shape, and color of heart.

Blood vessels attached to the heart.

Inner surface and lining.

Cavities; position and names.

Valves; location, names, divisions.

Walls; comparison as to thickness.

Sketch of aorta, showing left semilunar valve.

The Human Heart does not differ materially in structure from the heart which has been studied. It is about the size of the clinched

fist of the owner, and is situated very near the center of the thoracic cavity. It is pear-shaped and is so placed that the small end extends downward and to the left. The student should consult some text on Physiology for information on the structure of the heart not revealed by the dissection. Make a sectional drawing of heart, showing cavities, valves, and large blood vessels connected with



Complete this sectional view of heart. it. Indicate by arrows the passage of blood through the two sides of the heart.

How the Heart Does Its Work. The heart is a hollow muscle and does its work by contracting and relaxing. When it contracts its cavities are closed and the blood is forced from them. When it relaxes the cavities open and the blood flows in to refill them. Valves prevent the backward flow of blood. How? The heart's action may be readily illustrated in the following manner:

Procure a syringe bulb with an opening in each end. Attach a rubber tube to each end of bulb, letting the tubes reach into two tumblers containing water. By alternately compressing and releasing the bulb, water is pumped from one vessel into the other. The bulb may be taken to represent one of the ventricles. What action of the ventricle is represented by compressing the bulb? What by releasing the pressure?

By making the proper connections with a greater length of tubing and filling the whole with water the entire circulation may be represented. Make a sketch showing the arrangement of the valves in the syringe bulb.

Section of syringe bulb showing valves.

Arteries and Veins. These are cylindrical tubes, connected with the heart, through which the blood passes. The arteries receive the blood from the ventricles and permit it to pass through them and their branches to capillaries in all parts of the body. ⁴ In its return to the heart from the capillaries the blood passes through the veins.

Arteries and Veins Compared.

Observation. Examine carefully the artery and vein saved from the dissection of the heart. Compare with reference to thickness of walls, elasticity, and toughness. Which stand open without pressure from within? Separate each into its layers or coats.

Both arteries and veins have three coats. The *inner* coat consists of flat, thin cells, united at their edges, and is called the *endothelium*. It is continuous with the lining membrane of the heart. The *middle* coat consists mainly of non-striated muscular tissue. In the veins it is very thin. The *outer* coat is connective tissue. In arteries it is thick and highly elastic.

Other differences between arteries and veins are as follows: 1. Veins contain valves; arteries do not. 2. Arteries carry blood rich in oxygen toward the tissues; veins carry blood deficient in oxygen from the tissues. (Pulmonary arteries and veins are exceptions.) 3. In the arteries the blood is under greater pressure and moves faster than in the veins. 4. The veins taken together hold more blood than the arteries.

Advantage of Elasticity of Arteries. 1. To prevent bursting of arteries when an excess of blood is emptied into them from the ventricles. 2. To keep the blood under pressure while the ventricles are relaxing.—By the contraction of the ventricles the arteries are filled over full and have to swell out to make room for the excess of blood. While the ventricles are relaxing, the arteries exert their elastic force to keep the blood flowing steadily into the capillaries.

Experiment. Close up one end of a piece of artery six or eight inches long (the aorta of a calf or sheep) and fit a stopper, having a pointed glass tube through its center, in the other end. With a force pump or syringe bulb force water into the artery. Observe (1) that the artery swells and may be filled over full and (2) that water is forced out through the little opening in the artery when there is no pressure from the pump.

The Pulse, felt by placing the finger over an artery near the surface of the body, is due to the swelling of the elastic artery at each contraction of the left ventricle.

The Purpose of Valves in the Veins is to enable the contraction of muscles over the body to assist in propelling the blood. When muscles contract they press against the sides of the veins and tend to empty them. Since the valves open in the direction of the flow of the blood, they are closed by any backward motion. The force of muscular contraction is thus made to push the blood forward.

Observation. Exercise the arm a few minutes to increase the circulation. With the finger stroke one of the veins upward toward the shoulder. Much of the blood can be forced out of it. Now stroke the vein toward the hand. The blood is not forced backward but the vein swells instead, the swelling being greatest at one or two places resembling "knots." These knots mark the position of valves which prevent the return of blood to the hand.

In structure the valves in the veins are like the semi-lunar valves of the heart. They are formed by a folding of the inner coat of the vein.

Important Arteries. The two main arteries are the *pulmonary* and the *aorta*. The first receives blood from the right ventricle and through its divisions, distributes it to all parts of the lungs. The second by its branches distributes the blood through the entire body. To obtain a practical knowledge of the arterial system, the aorta and its branches should be traced out in some small animal, as a cat or rabbit. To secure the best results, the arteries should be injected with coloring matter. (See Appendix.) The following description will serve as a guide to the main arteries:

The aorta connects with the left ventricle, leaving the heart at its upper portion. From here it passes over as an arch and descends nearly in front of the spinal column. It passes through the diaphragm and down to the lower portion of the abdomen, where it divides. The portion in the thorax is called the *thoracic aorta*; that in the abdomen, the *abdominal aorta*.

The first branch to leave the aorta consists of two parts which go to the heart, called the *coronary* arteries. These leave just above the semi-lunar valves.

The second leaves at the right upper part of the arch and is called the *innominate* artery. It is very short, and divides into the right *common carotid* and the right *subclavian* artery. The right subclavian artery passes into the right arm. In the arm pit it is called the *axillary*, and in the arm, the *brachial* artery. In the forearm it divides into the *ulnar* and *radial* arteries, which lie along the bones

of the same name. These unite in the palm of the hand, forming the *palmar arch*. The right common carotid ascends the right side of the neck and divides into the *internal carotid*, supplying the right side of the brain, and the *external carotid* supplying the right side of the face and outer right side of the skull.

The *third* branch leaves the aorta near the top of the arch and is called the *left common carotid*. It branches in an exactly similar way to the right common carotid.

The *fourth* branch leaves at the left upper portion of the arch and is called the *left subclavian artery*. It passes to the left arm and forms divisions corresponding to those of the right subclavian artery.

Other branches from the *thoracic aorta* are the *intercostal arteries*. One follows each rib, running in a groove on the under side.

The branches from the *abdominal aorta*, of importance are: The *phrenic*, going to the diaphragm; the *coelic axis* which divides at once into the *hepatic* (to the liver), the *gastric* (to the stomach), and the *splenic* (to the spleen); the *superior* and *inferior mesenteric* going to the intestines; and the *renal* arteries going to the kidneys.

The *two divisions* of the lower end of the aorta are called the right and left *common iliac arteries*. Each of these divides, first into an internal and an external branch. The internal goes to the organs of the pelvic region, while the external (the larger) passes into the leg. It extends down by the side of the femur bone where it is called the *femoral*, and back of the knee where it is the *popliteal* artery.

Below the knee it divides into the *anterior* and *posterior tibial* arteries and these unite in the foot in an arch similar to the palmar arch.

All the arteries named divide and subdivide until their minute portions reach all parts of the body. Trace in the cut the general course of the aorta and its branches through the body.

Important Veins. The large veins lie alongside of the large arteries and have corresponding names. Those from the arms, head, and



Sketch an outline of the aorta and its branches.

upper part of the trunk unite to form the *descending vena cava* which connects with the right auricle from above. The veins from the lower extremities, viscera, and lower part of the trunk unite to form the *ascending vena cava* which connects with the right auricle from below. The *pulmonary* veins (four in number) and their branches pass the blood from the capillaries of the lungs to the left auricle. The *portal* vein, the large vein of the abdomen, receives blood from stomach and intestines and conveys it to the liver.

The Capillaries consist of a network of very fine blood vessels which connect the terminations of the smallest arteries with the beginning of the smallest veins. With a few exceptions, they penetrate and permeate all parts of the body. They differ from both arteries and veins in being very small and in having very thin walls. Their only coat consists of a very thin layer of endothelial cells placed edge to edge.

Observation. Study with a compound microscope the circulation of blood through the capillaries in the web of a frog's foot. For an extended observation it is best to remove the frog's brain. (See Appendix.) The frog may be attached to a thin board which has an opening in one end over which the web of the foot may be stretched. Threads should extend from two of the toes to pins driven in the board to secure the necessary tension of the web. The appearance is truly wonderful, but allowance must be made for the fact that the *motion* of the blood is also magnified and that it really moves much more slowly than it appears to move under the microscope.

The Function of the Capillaries is to distribute the blood among the tissues. On account of the extent to which they penetrate the tissues, the blood is brought very near the individual cells. Then the thinness of their walls permits of an easy exchange of materials between the blood within the capillaries and liquids on the outside.

Sketch of capillaries in frog's foot.

The Circulation Traced. The blood passes through the circulatory organs in the following order: Right auricle, tricuspid valve, right ventricle, right semi-lunar valve, pulmonary artery and its branches, capillaries of lungs, pulmonary veins, left auricle, bicuspid valve, left ventricle, left semi-lunar valve, aorta and branches,

systemic capillaries, veins, vena cava ascending and descending, and then again into right auricle. At the lungs the blood gives up carbon dioxid and receives oxygen. In the systemic capillaries it gives up its oxygen and receives carbon dioxid and other impurities.

The circulation of the blood through the lungs is called the *pulmonary* circulation; through the body, the *systemic*; through the liver, the *portal*; through the kidneys, the *renal*; and through the heart itself, the *coronary* circulation.

Health Suggestions. The vigor of the circulatory system is largely dependent upon one's habits of living. As a rule those conditions which are favorable to the general health are beneficial to the organs of circulation. Regular physical exercise is one of these conditions and its importance with reference to the circulation cannot be overestimated. The presence of valves in the veins shows that part of the force to move the blood must come from the contraction of muscles surrounding the veins. It is also known that moderate physical exercise aids indirectly in keeping up the vigor of the heart's action. On the other hand, violent and prolonged physical exertion overtaxes the heart and endangers the walls of the blood vessels.

Construct a diagram showing the course of the blood through the organs of circulation.

The organs of circulation are under the control of the nervous system. Hence it frequently happens that a weakness in this system results in a disturbance of the circulation. Many of the so-called

“heart troubles” are due to an overtaxed or weakened condition of the nervous system and disappear when it recovers its normal condition.

Stimulants and narcotics, mainly through their effect on the nervous system interfere with the healthy action of circulatory organs. They should be carefully avoided.

Tight fitting clothing, on any part of the body, interferes with the free circulation and for this reason should not be worn.

The blood should circulate *uniformly* through the different parts of the body. A continued excess of blood in certain parts, especially the brain, may lead to serious results. Congestion in any part is generally relieved by activity of *other* parts of the body or by irritating them in some way. We have an example of this in the relief of blood pressure on the brain which follows placing the feet in hot water.

Suggested Topics for Further Study. 1. Quantity of work performed by the heart. 2. Sounds of the heart. 3. Effect of bodily exercise on the activity of the heart.—Count the number of pulsations per minute (a) when lying down, (b) when in a sitting posture, (c) when standing, (d) after walking, and (e) after running. 4. Circulatory systems of other animals. Compare systems of the insect, fish, reptile, and warm-blooded animal. 5. Effect of alcohol and tobacco on the organs of circulation. 6. Checking the flow of blood from wounded arteries and veins.

References. On structure of heart, S., 103-109; F. and S., 78-86; J., 94-95. On amount of work done by the heart, S., 110, J., 107. On structure of blood vessels, C., 75-78; S., 112-114; J., 90-93; F. and S., 95-100. On effect of muscular contraction on circulation, S., 117; C., 83, 84. How the heart does its work, C., 72-75; F. and S., 87-90. Effect of alcohol on the circulation, S., 118-121. Effect of tobacco on the heart, S., 122.

Practical Questions. 1. Of what special value to science was the discovery of the circulation? 2. State the necessity for a circulating liquid in the body. 3. Show how the heart does its work. 4. Of what use are the valves in the heart? In the veins? 5. State the necessity for the difference in structure between the right and left ventricles. 6. Of what advantage is the elasticity of the arteries? 7. How is blood forced from the capillaries back to the heart? 8. Show how the heart is able to rest about six hours out of every twenty-four. 9. What is the special work of the capillaries? 10. Why should *severe* mental or physical labor be avoided for a time after taking a full meal? 11. Trace the blood through a complete circulation, beginning with the left auricle.

CHAPTER IV.

Lymph and the Lymphatics.

Necessity of the Lymph. The blood, it will be remembered, moves everywhere through the body in a system of *closed* tubes. It does not come in direct contact with any of the cells of the body except those which float in it and those which line the interior of the blood vessels. There is need of a quiet liquid between the blood and the cells to convey materials from one to the other. The lymph occupies this position and does this work. Make a sketch showing the relative positions occupied by the blood, the lymph, and the cells.

The Chief Source of the Lymph is the plasma of the blood. As before described, the walls of the capillaries consist of a single layer of endothelial cells placed edge to edge. Partly on account of the pressure on the blood in the capillaries and partly on account of the natural tendency of liquids to pass through animal membranes, a considerable portion of the plasma penetrates the thin walls and enters the spaces occupied by the lymph.

Relative position of blood,
lymph, and cells.

Other sources of the lymph, of less importance, are the outward flow of liquids from the cells and the absorption of liquids from the alimentary canal. Liquids absorbed through the skin on the outside of the body also become a part of the lymph.

The Composition of the Lymph, as would be expected, is quite similar to that of the blood. In fact, nearly all the important constituents of the blood are found in the lymph, but in different proportions. Food materials for the cells and fibrin factors, exist in smaller proportions than in the blood, while impurities from the cells exist in larger proportions. The number of white corpuscles is slightly greater than in the blood, while there is an absence of red corpuscles.

Physical Properties. The lymph is a colorless liquid slightly heavier and denser than water, though not so dense as the blood. It has no well defined odor or taste. It has the power of coagulating, but coagulates more slowly than the blood.

Kinds of Lymph Vessels. Most of the lymph of the body lies in the minute cavities surrounding the cells. These are called *lymph spaces* and correspond, in a way, to the capillaries. Connected with these are great numbers of slender tubes, with thin walls, called *lymphatics*. They may be likened to the veins and, like the veins, contain valves. The lymphatics from different parts of the body gradually converge toward two main tubes. One of these, the *right lymphatic duct*, empties into the right subclavian vein, where it is joined by the right jugular vein. The other, the *thoracic duct*, empties into the left subclavian vein, where it is joined by the left jugular vein.

The lymphatic tubes which join the thoracic duct from the small intestine are called the *lacteals*. These differ somewhat in structure from those found in other parts of the body, their special function being to absorb digested fats from the small intestine.

Movements of the Lymph. Though the lymph may be regarded as a comparatively quiet liquid, it has three well defined movements as follows: 1. A current passing through it from the the capillaries toward the cells. 2. A current from the cells toward the capillaries. 3. A movement of the entire body of lymph along the lymph channels, toward the larger lymph vessels.

Return of Lymph to the Blood. From the lymph spaces, lymph enters the lymphatics. It passes through these tubes until it enters either the thoracic duct or the right lymphatic duct. From these it passes into the subclavian veins. Show by a sketch the connection of the lymph vessels in the different parts of the body with the blood vessels.

Lymph from the right side of the head, right arm, and right side of chest, passes into the blood through the right lymphatic duct. Lymph from the lower extremities, abdomen, left side of chest and head, and left arm, passes into the blood through the thoracic duct.

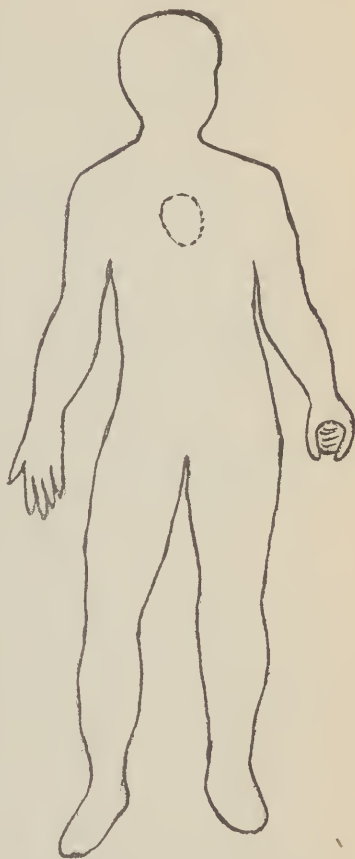
Causes of Flow of Lymph.

There is no force pump, like the heart, connected with the lymphatics and the causes of the flow of lymph are somewhat obscure. The following seem to be the chief causes:

1. *Blood pressure in the capillaries.* The plasma which is forced through the capillaries makes room for itself by pushing a portion of the lymph out of the lymph spaces. This in turn pushes on the lymph in the tubes which it enters. In

this way the pressure is passed on to the whole body of lymph.

2. *By the contraction of muscles against the walls of the lymph tubes.* Any pressure on the sides of the lymph tubes tends to close them up and push the lymph past the valves which, by closing, prevent its return. It is thus seen that the effect of contracting muscles is the same on the lymph as on the blood in the veins.



Complete the sketch showing the connection of the lymph vessels with the blood vessels.

The Lymphatic Glands are small, solid bodies situated along the course of the lymphatics. They vary in size, some of the largest being an inch or more in length. The lymphatic tubes generally open into them on one side and leave them on the other. Each gland is made up of a mesh-work of connective tissue fibers, within which is found large numbers of white blood corpuscles. State the function of these glands.

Interchange of Materials at the Cells.

Liquid food and oxygen in passing from the blood through the lymph into the cell must penetrate both the wall of the capillary and the wall of the cell. These are likewise penetrated by the impurities which flow from the cell back to the blood. The passage of materials between liquids separated by animal membranes, takes place according to the principle known in Physics as *osmosis* or *dialysis*.

Osmosis Illustrated. If a vessel with an upright membranous partition be filled on one side with water containing salt, and on the other side with water containing sugar, an interchange of material will take place through the membrane until the same proportion of salt and sugar exists in the separated liquids.

Experiment. Separate the shell from the lining membrane, at one end of an egg, over an area an inch in diameter. To do this without injuring the membrane, the shell must be broken into small pieces and be picked off with a pair of forceps or a small knife blade. Fit a small glass tube, 8 inches long, into the other end, so that it shall penetrate the membrane and pass down into the yolk. Securely fasten the tube to the shell with beeswax, and set the egg in a small tumbler partly filled with water. Examine in the course of half an hour. What evidence now exists to prove that water has passed through the membrane into the egg? Has any of the egg substance passed into the water? Make a sketch of the tumbler and the egg, showing by arrows the passage of material.

The Conditions Under Which Osmosis Occurs are as follows:

1. The liquids on the two sides of the membrane must be *unlike* either in composition or density. In case of a difference in density

the greater flow of liquid is toward the denser substance. 2. Both liquids must be capable of wetting or penetrating the membrane. If but one liquid wets the membrane, the flow will take place in but one direction. 3. The liquids must have enough attraction for each other to mix readily.

Give two reasons for the greater flow of the water into the egg in the previous experiment.

Osmosis at the Cells. Oxygen and food materials which are found in great abundance in the blood, are less abundant in the lymph and still less abundant in the cells. According to the principle of osmosis the flow of oxygen and food material will be from the capillaries toward the cells. On the other hand the impurities are most abundant in the cells where they are formed, less abundant in the lymph, and least abundant in the blood. Hence the impurities will flow from the cells toward the capillaries.

The Work of Water in these exchanges should not be overlooked. The materials to be exchanged are dissolved in water. Water then, by keeping them in a liquid condition, supplies the conditions necessary for osmosis to take place.

Massage. Too great an accumulation of lymph in any part of the body causes swelling. This may frequently be reduced by a process of rubbing, pressing, and kneading, known as massage. The force applied in this way on the outside of the body has the same effect on the veins and lymph tubes as muscular contraction from within. Where one is too weak for exercise or is disabled in any part of the body this *passive exercise* may be substituted with good results for active exercise taken in the usual way.

References. On the lymph, F. and S., 104; J., 86; C., 98; S., 88. On the lymph vessels, S., 88, 89; F. and S., 104, 105; J., 100; C., 98. On flow of lymph, C., 99. On massage, C., 103.

Practical Questions. 1. Compare lymph and water with reference to density, color, and composition. 2. Compare blood and lymph with reference to composition, physical properties, and movement through the body. 3. Compare the lymph tubes with the blood vessels with reference to general structure and the different kinds. 4. Show how blood pressure at the capillaries causes a flow of the lymph. 5. Trace the lymph in its flow from the right hand to where it enters the blood. From the feet to where it enters the blood. 6. What conditions prevail at the cells to keep the oxygen continually flowing in one direction and impurities in the opposite direction? 7. What part does water play in the exchanges at the cells?

CHAPTER V.

The Atmosphere.

As before stated, one purpose of the blood is to carry oxygen to the cells. This supply of oxygen is obtained from the atmosphere. In this and other respects the atmosphere sustains a most important relation to the plan of the body. It is necessary therefore that we study briefly its important constituents and properties.

Composition of the Atmosphere. The atmosphere completely surrounds the earth, forming an envelope at least fifty miles in depth. It is composed of colorless gases, the greater amount of it being made up of *oxygen* and *nitrogen*. The former comprises about one-fifth and the latter nearly four-fifths of the entire atmosphere. Mingled with the oxygen and the nitrogen, but in small quantities, are a number of other substances. Of these, *carbon dioxid* and *watery vapor*, are of greatest importance.

Properties of Oxygen.

(Four large mouthed bottles of oxygen are needed for the following experiments. For methods of collecting see Appendix.)

Experiment 1. Examine a bottle of oxygen, noting if it has color. Insert a small burning splinter in the upper part of the bottle and observe the change in the burning. Remove quickly and extinguish the flame, leaving only a spark on the end of the splinter. Lower the spark into the oxygen and observe the result. Repeat until the oxygen in the bottle is exhausted.

Exp. 2. Hollow out the end of a short piece of crayon, fasten a wire holder to it, and fill the cavity with powdered sulphur. Ignite the sulphur in the flame of an alcohol lamp and lower it into a bottle of oxygen. Observe the effect on the burning, the color of the flame, and the material formed in the bottle by the burning.

Exp. 3. Bend a small loop on the end of a piece of picture wire. Heat the loop in a flame and then insert in some powdered sulphur. Ignite the melted sulphur which adheres and insert it quickly in a bottle of oxygen. Observe the dark brittle material which is formed by the burning of the iron. It is a compound of oxygen and iron, similar to iron rust and has been formed *by their uniting*.

State effect of oxygen on the burning of things which also burn in air.

Describe burning of the iron.

What proof is furnished by these experiments that matter in burning is not destroyed?

Oxygen causes substances to burn *by uniting with them*. The new substances formed are different from both the oxygen and the things with which it unites. Heat and light result from the rapidity of the uniting. Oxygen is able to unite in this rapid manner on account of the *intense affinity* or attraction which it has for certain substances. It is only the free or uncombined oxygen that is capable of uniting with substances. For this reason that which is already united with substances is unable to support combustion.

Properties of Nitrogen.

Experiment. 1. Insert a long, burning splinter in a large mouthed bottle or jar, filled one-fourth full of lime water. (See Appendix.) Keep the top closely covered with a piece of cardboard while the splinter is burning. The carbon and hydrogen of the splinter unite with the oxygen of the air, leaving the nitrogen and such impurities as are formed by the burning. Keeping the top tightly closed, shake the jar to bring the lime water in contact with the enclosed gases. If fresh air gets into the jar the burning and shaking should be repeated. The lime water unites with most of the impurities, leaving only the nitrogen.

2. Note that the nitrogen in the jar is colorless. Test its ability to support combustion.

Compare with oxygen with reference to ability to support combustion.

The affinity of nitrogen for other substances is very slight. Hence it is unable to support combustion as oxygen does. In the atmosphere it serves the purpose of diluting or weakening the oxygen.

Carbon Dioxid is a compound of carbon and oxygen and is formed whenever these substances unite. Its chemical symbol CO_2 , indicates one part of carbon and two parts of oxygen. The test for CO_2 is lime water, with which it unites to form carbonate of lime.

When this occurs the lime water, which is colorless, becomes milky-white in appearance.

Experiment. 1. (a.) Attach a piece of charcoal (carbon) no larger than the end of the thumb to a piece of wire. Ignite the charcoal and lower it into a vessel of oxygen. Observe its combustion. Let it remain until it ceases to burn. Note that in burning the piece of carbon has diminished in size and the oxygen has disappeared. Has anything been formed in their stead?

(b) Remove the charcoal and add a small amount of lime water to the bottle. Cover the bottle and bring the gas and lime water in contact by shaking. Note change in color of the lime water. What does it indicate?

2. Burn a splinter in a large vessel of air, keeping the top covered. Add lime water and shake. Note and account for the result.

3. Place several small pieces of limestone (marble) in a fruit or candy jar holding at least one-half gallon. Barely cover the limestone with water and then add hydrochloric acid until a gas is rapidly evolved. This gas is carbon dioxide.

(a) Examine it to see if it possesses color.

(b) Insert a burning splinter and notice the result.

(c) Blow a small soap bubble on the end of a tube and disengage it in the jar. (A tube $\frac{3}{8}$ inch in diameter is best for this purpose.)

(d) Tip the jar over the mouth of the tumbler, as you would to empty it of water, though not far enough to spill the acid. Then insert a burning splinter in the tumbler. Result?

State conclusions with reference to weight and color of CO_2 and its effect on combustion.

Removal of Carbon Dioxid from the Atmosphere. It is readily seen that, if the combustion of carbon removes oxygen from the atmosphere and replaces it with carbon dioxide, the whole atmosphere would in time become deficient in the one and contain too much of the other. This condition is prevented through the agency of vegetation. Plants absorb the carbon dioxide from the air, decompose it, build the carbon into compounds that become a part of the plant, and return the oxygen to the air. In doing this, they not only preserve the necessary proportion of oxygen and carbon dioxide in the atmosphere, but also put the carbon and oxygen in such a condition that they may again unite. This process which takes place in the leaves, goes on only while sunlight is acting on the plant.

Watery Vapor is water in the form of a gas. Water, whether it occurs as a solid (ice), liquid, or gas, is a compound of hydrogen

and oxygen. Its chemical symbol, H_2O , indicates two parts of hydrogen and one of oxygen in its composition. Watery vapor is always present in the atmosphere, but in varying proportions. It gets into the air by evaporation from the surface of water, by its escape from the bodies of plants and animals, and by its formation in the combustion of substances containing hydrogen.

It is removed from the air principally by condensation, which results from a portion of the atmosphere becoming cooled. When this occurs the watery vapor may fall as rain or snow (depending on the temperature), or be deposited as dew.

Account for the collection of moisture on the outside of a pitcher of cold water.

Account for the *formation* of the water which collects on the inside of a cold lamp chimney, when placed on a lighted lamp.

Atmospheric Pressure.

Experiment 1. Wet a circular disk of leather, having a strong cord attached to the center, and press it against the smooth surface of the blackboard. An attempt to jerk it away fails because the pressure of the air holds it tight.

2. Place a stiff piece of paper over the mouth of a tumbler filled with water. Keeping the paper in position invert the tumbler. Atmospheric pressure holds the water in the tumbler.

3. Suck the air from the mouth of a small bottle, letting it come in contact with the end of the tongue. Atmospheric pressure will cause it to adhere to the end of the tongue.

4. Stretch a thin sheet of rubber (the kind used by dentists) over the mouth. By lowering the jaw, make a partial vacuum in the mouth. Atmospheric pressure pushes in the rubber.

Where an air pump can be obtained many other interesting experiments, illustrating the pressure of the air, may be performed.

Atmospheric pressure is due to the weight of the air. It is greater at low places than on high elevations because there is more air above the low places to press down. At the sea level it averages nearly fifteen pounds to the square inch. This pressure is not felt on the body because the air which penetrates the tissues exerts an *outward* pressure which balances it.

Inequality of atmospheric pressure causes motion. The motion may be confined to the air itself or communicated to other bodies. The *direction* of the motion is *from the place of greater to the place of less* pressure.

Experiment. Suck the air from one end of a glass tube, which has the other end in water. Water rises in the tube, because the pressure of the air on the inside of the tube is less than the pressure on the surface of the water outside of the tube.

Other Properties of the Atmosphere of importance in our study are elasticity, mobility, and diffusibility.

Its *elasticity* is shown by its power to regain its former volume after having been compressed, and is well illustrated by the boy's pop-gun. Since air returns exactly to its former volume, after the removal of pressure, it is said to be *perfectly elastic*. The pressure which it exerts in returning to its former volume is called its *elastic force*.

Mobility may be described as freedom of motion. On account of the degree to which air possesses this property it flows easily from a place of greater to a place of less pressure. For the same reason it offers little resistance to the movement of bodies through it.

Diffusibility refers to the *mixing* of gases regardless of their weight. If a tumblerful of carbon dioxid, a heavy gas, were exposed to the air it would soon leave the tumbler and mix with the surrounding air. This will happen even when a porous covering separates the carbon dioxid from the air. Diffusion is due to the rapid motion of the molecules of the gases. In the atmosphere it serves the purpose of keeping the different gases mixed.

What the Atmosphere Does for the Body. 1. It supplies the body with oxygen and receives the gaseous impurities which escape from it.

2. It supplies the pressure which makes it possible to take air into and expel it from the lungs.

3. It serves as a carrier of sound waves, by means of which, hearing is made possible.

Practical Questions. 1. Why will not the oxygen in water support combustion? 2. State the objections to an atmosphere of pure oxygen. 3. If substances which burn are not destroyed, what becomes of them? 4. Would life be possible without an atmosphere? Why? 5. In what different ways does carbon dioxid get into the atmosphere? How is it removed? 6. In what different ways does watery vapor get into the atmosphere? How is it removed? 7. Define these terms: chemical affinity, combustion, element, molecule, compound, combustible, and supporter of combustion.

CHAPTER VI.

Respiration.

Respiration, or breathing, is carried on by alternately taking air into and expelling it from special contrivances in the body called the lungs. The act of taking air into the lungs is known as *inspiration*; that of expelling it, *expiration*.

The Purpose of Respiration is indicated by the changes which air undergoes while in the lungs.

Experiment. 1. Fill a quart jar even full of water. Place a heavy piece of cardboard over its mouth and invert it, without spilling, in a pan of water. Inserting a tube under the jar, blow air that has been held as long as possible in the lungs, into it. When filled with air, remove the jar from the pan, but keep the top well covered. Insert a burning splinter and observe the result. This proves the absence of what? Pour in a little lime water and shake to mix with the air. Account for the result.

2. Blow the breath against a cold window pane. Note and account for the result.

State results and conclusions.

Air taken into the lungs in ordinary breathing, parts with about five per cent. of itself in the form of oxygen and it receives about four per cent. of carbon dioxid, considerable watery vapor, and a small amount of other impurities. These changes suggest a two-fold purpose of respiration:

1. To obtain from the atmosphere the supply of oxygen needed in the body. 2. To transfer to the atmosphere certain materials (impurities) which must be removed from the body.

The Respiratory Organs, taken together, form an apparatus for dealing with matter in the gaseous state and are constructed with special reference to the properties of the atmosphere. They provide for four different things:

1. For bringing the air very near a large surface of blood. The special contrivances for doing this are called the *air vesicles*.

2. For a continuous passage way between the air vesicles and the outside atmosphere. The tubes which provide this passage way are called the *air passages*.

3. For a cavity for holding the main organs of respiration. This cavity is enclosed by the walls of the *thorax* or chest and is called the *thoracic* cavity.

4. For the necessary pressure for forcing the air through the air passages. This is furnished by muscles situated for the most part within the walls of the thorax.

The Lungs are two sack-like organs suspended in the thoracic cavity. They consist chiefly of the walls of the air vesicles, smaller air passages, and blood vessels, and occupy most of the space not taken up by the heart.

Observation. Secure from a butcher the lungs of a sheep, calf, or hog. The windpipe and heart should be left attached and the specimen kept in a moist condition until used. Study in the following order:

1. Examine the large open tube (the trachea) and the closed tube lying back of it (the oesophagus). Observe the cartilaginous rings in the trachea. What purpose do they serve? Remove one and make a drawing of it.

2. Insert a tube in the trachea and inflate the lungs. About how many times is their volume thus increased?

3. Examine the thin membrane (the pleura) enclosing the lungs. Strip off a piece and test its elasticity.

4. Sever the small upper lobe from the remainder by cutting the bronchial tube. Split this tube a short distance into the lung, observing its smooth lining and the openings of smaller tubes branching off from it. Are the rings in these tubes circular or like those in the trachea? Make cross sections of this portion of the lung and find the openings of the lesser bronchial tubes.

5. Follow the trachea down to where it branches to form the bronchi. Find a branch of the pulmonary artery which approaches one of the bronchi and cut

both artery and bronchus from their connections. Now trace the bronchus and artery into the lung. Observe that as one branches, the other branches, until the smallest divisions are reached. The pulmonary veins also lie alongside the bronchial tubes, but are not so easily traced as the arteries.

6. Place a piece of lung upon water. In floating, what proportion of it is submerged? Inference.

7. Beginning with one of the bronchi, strip all the outer material from the tube and its branches. Make a drawing of it in this condition.

1. Comparison of trachea and oesophagus.

2. Description of cartilaginous ring with drawing, giving use.

3. Effect of blowing air into lungs.

4. Description of pleura.

5. Relation of blood vessels to the bronchial tubes.

6. Describe the branching of the trachea. Make a drawing, showing the branches.

7. Weight of lung compared with weight of water.

8. Name the different tissues found in lungs.

The Air Passages, named in the order that air goes through them as it enters the lungs, are the nostrils, (pharynx), larynx, trachea, bronchi, bronchial tubes, and lesser bronchial tubes. As the air passes through the nostrils it comes in contact with a large surface of moist mucous membrane and is warmed, moistened, and freed from particles of dirt. Only the upper part of the pharynx can properly be classed as an air passage. The lower portion is a part of the food canal, while the middle part provides a suitable cross-roads for the air tract and the passage way for the food.

Air may also enter the pharynx through the mouth. This is necessary in many instances, but in ordinary breathing the air should pass through the nostrils. The larynx will receive special study as the instrument of the voice.

Leaving the lungs the air goes through the same passages, but in the reverse order. To enable the air to move easily through the different passages, it is necessary that they be kept *open* and *clean*.

The air passages are kept open by special contrivances found in their walls. In trachea, bronchi, and larger bronchial tubes these consist of imperfect rings of cartilage. In the

smaller tubes the cartilage disappears, its place being taken by stiff connective tissue. The walls of the larynx contain strips and plates of cartilage, while the nostrils and pharynx are kept sufficiently open by their bony surroundings.

Show by a drawing the position of the pharynx with reference to mouth, nostrils, trachea, and oesophagus.

The air passages are kept clean by certain cells designed especially for that purpose, known as the *ciliated epithelial cells*. The peculiarity of these cells is their small, hair-like projections, called *cilia*. Ciliated epithelial cells line the mucous membrane in most of the air passages and are so placed that the cilia extend into the open space in the tubes. The cilia keep up an inward and outward wave-like motion which has greater force in the *outward* direction. The effect of this motion is to carry any foreign matter to where it may be easily expelled from the lungs.

Drawing to show form of ciliated epithelial cells and their position in a bronchial tube.

The Air Vesicles are the small membranous sacs found at the ends of the smallest bronchial tubes. They measure about 1-100 of an inch in diameter and a cluster of them is found at the end of each tube. Each is composed of a lining of thin, flat cells, resting upon a delicate support of connective tissue which is very elastic. Within the walls of the vesicle is a net work of capillaries through which the blood flows. This arrangement brings the air very near a large surface of blood and renders possible the exchange of gases. It is thus seen that the air and blood do not come in direct contact but that the exchanges take place through the capillary walls and the lining of the air vesicles.

1.

2.

The Supply of Blood to the Lungs is provided for through the pulmonary blood vessels. The pulmonary artery coming from the right ventricle, sends branches to all parts of the lungs. A division of this artery follows each bronchial tube down into the lungs and finally terminates in the capillaries which surround the air vesicles with which the tube connects. From the capillaries the blood is returned to the heart by the pulmonary veins. These lie alongside the

Drawings to show the structure of the air vesicles and their connection with the smallest bronchial tubes.

arteries and bronchial tubes and unite to form four veins, two from each lung, which enter the right auricle.

The lungs also receive blood through branches from the aorta which supply nourishment to the different tubes and also to the tissues of the lungs.

The Thorax, or chest, is that part of the trunk between the neck and the abdomen which encloses a space, known as the thoracic cavity. The framework of the thorax is furnished by the ribs, the portion of the spinal column with which they connect in the back, and the sternum or breast bone with which they connect in front. The ribs do not encircle the cavity in a horizontal direction but slant downward toward the front. The thoracic cavity is separated from the cavity below by a partition called

The Diaphragm. At its edges the diaphragm is attached to the walls of the thorax where they join the abdominal walls. At the outer margin is a layer of muscles which pass from the walls on the outside to a strong layer of connective tissue in the center. The diaphragm is naturally in an arched condition, being kept in this form by pressure from the organs below.

The Muscles of the Thorax, called into play in ordinary breathing, are chiefly of two kinds, known as the *elevators of the ribs* and the *intercostal* muscles. The first pass from the back portion of the ribs to the vertebrae above. The second form oblique bands between the ribs, which are arranged in two sets, known as the external and internal intercostal muscles.

The Pleura is a thin, elastic membrane, which covers the outside of the lungs and lines the inside of the chest walls. The part covering the lungs joins with the part lining the walls, so as to form a closed sac.

In this sac is secreted a liquid which diminishes friction between the lungs and their surroundings.

Drawing to show position
of pleura in thoracic cavity.

An extension of the pleura, passing from the lungs to the diaphragm below and the chest walls in front, divides the thorax vertically into two halves, each distinct from the other. The left lung is suspended in one of these divisions; the right lung in the other.

How Air Is Brought Into and Expelled From the Lungs.

The principle involved in breathing is that *air flows from a place of greater to a place of less pressure*. The construction of the thorax adapts it to the application of this principle. Its walls are air tight and it is able, by changing the size of the cavity within it, to produce alternately *a place of less and a place of greater pressure* than that of the atmosphere on the outside of the body.

The lungs are suspended from the upper portion of the thoracic cavity and are always sufficiently filled with air to keep their outer surface pressed against the chest walls. The trachea and the upper air passages provide the only opening to the outside atmosphere. When the thorax is enlarged, making an area of less pressure within, the greater pressure of the atmosphere on the outside, forces the air into the lungs, causing them to expand and fill the extra space within the cavity. When the thorax is diminished in size the air within the lungs is compressed, causing it to exert greater pressure by its elastic force than the atmosphere exerts on the outside. This causes air to flow out until the equality of pressure is again restored.

In this connection a hand bellows, such as used in kindling fires, may be studied with profit, its action being similar to that of the thorax. Observe that when the sides are spread apart air flows into the bellows. When they are pressed together the air flows out. If a sac were hung in the bellows with its mouth attached to the projecting tube and the valve in the side of the bellows closed it would represent almost exactly the plan of the breathing organs.

Experiment. With a tape line take the circumference of the chest of a boy, when he has expelled from the lungs all the air possible. Take it again when he has them inflated to their utmost capacity. The difference in the measurements represents his relative chest capacity. What does this experiment show with reference to the cause of breathing?

How the Thorax Changes its Capacity. The space within the thorax *is increased* by the elevation of the ribs and the depression of the diaphragm. The former process increases the transverse diameter; the latter the longitudinal. The ribs are raised mainly by the action of the *elevators* of the ribs, and by the *outer set of inter-*

costal muscles. The diaphragm, being naturally in an arched position, is depressed by the contraction of the muscles within it. As it lowers, it pushes down the contents of the abdomen.

Experiment. With five narrow strips of cardboard, one 8 inches long and the others 6 inches, construct a figure to represent the thorax. Let the long strip serve as the spinal column and one of the short ones as the breast bone. Fasten the others between them for ribs. The fastenings, which must admit of motion, may be made by simply pushing pins through the strips where they join.

Holding the piece representing the spinal column in a vertical position, raise and lower the piece representing the breast bone. When is the space between the upright pieces the greatest? Apply to the action of the ribs in increasing the thoracic cavity.



Insert diaphragm and indicate by dotted lines the changes which the cavities undergo during inspiration.

The capacity of the thorax is *diminished* by lowering the ribs and elevating the diaphragm. Ordinarily the ribs are lowered by their own weight. In forced expiration the *internal intercostal* muscles are brought into play. The diaphragm is *pushed up* by the contents of the abdomen, which are pressed upon by the contraction of the abdominal walls.

To Estimate the Quantity of Air Breathed.

Experiment. (a) Fill a half gallon fruit jar even full of water, cover the top with a stiff piece of paper, and invert, without spilling, in a pan of water. Insert a tube under the jar and blow the air expelled from the lungs in *ordinary breathing* into the jar. Count the number of expirations required to fill the jar and then calculate the quantity breathed out during a single expiration. This equals the amount breathed in at an average inspiration, and is called the *tidal air*.

(b) Fill and invert the jar as before. This time, after an *ordinary* inspiration, empty the lungs as completely as possible. (A second vessel should be ready to receive the excess of air in case the jar should prove too small.) This air, less the tidal air, is called the *reserve air*.

The air that is left in the lungs after the forced expiration is called the *residual air*. In quantity it nearly equals the sum of the tidal and reserve air. Record results of experiment.

Tidal air..... Reserve air..... Residual air.....

The sum of these quantities gives the volume of the lungs, which in the average individual, is about one gallon. In forced inspiration the quantity may be increased about one-third.

The Interchange of Gases at the Lungs. though not fully understood, is supposed to result largely from the natural tendency of gases to *diffuse*. (See p.36.) Diffusion not only causes the mixing of the air entering the lungs with that already in the vesicles, but experiments prove that diffusion takes place between gases in a liquid, as the blood, and the air, even when an animal membrane encloses the liquid.

It is highly probable that the attraction between the haemoglobin of the blood and the oxygen of the air also plays an important part in the interchange of gases at the lungs.

Hygiene of Respiratory Organs. The liability of the lungs to attack from such a dread disease as consumption, makes questions touching their hygiene of first importance. Consumption never attacks sound lung tissue, but always has its beginning at some weak or enfeebled part of the lungs, which has lost its "power of resistance." Neither is consumption inherited as many suppose. Weak lung tissue, however, may be transmitted from parents to children and this accounts for the frequent appearance of consumption in the same family. Consumption, as well as the other respiratory affections, can in the majority of cases be *prevented* by an intelligent observation of well established laws of health.

Respiratory Health Rules. (Selected from various sources.)

1. Breathe through the nostrils.
2. Maintain an erect position both in sitting and standing.
3. Practice deep breathing sufficiently to insure the easy access of air to all parts of the lungs.
4. Wear clothing loose enough around the chest and waist to permit of perfect freedom in the respiratory movements.
5. Never permit a cold to settle on the lungs. If it cannot be relieved by counter-irritation a physician should be consulted.
6. Take active exercise in the open air. Exercise which causes a notable increase in the respiratory acts are of especial value in strengthening the lungs.
7. Avoid smoking and the use of alcoholic drinks. Tobacco smoke irritates the upper air passages, causing in some instances what is called "the smoker's sore throat." "Alcohol weakens the power of lung tissue to resist disease."

Ventilation. The health of the respiratory organs and of the entire body as well, demands that we breathe *pure* air. By pure air is meant that which contains the same proportion of oxygen as the general atmosphere. (How does breathing render air impure?) Ventilation is the process of bringing pure air into a room, and of getting rid of the air which is unfit for breathing purposes. Since warm air is lighter than cold air, suitable openings in the walls of dwellings enable currents of air to pass between the rooms and the outside atmosphere. Care must be taken to prevent drafts and too great a loss of heat from the rooms. The plan of ventilating must be adapted to the construction of the building, plan of heating, and the general condition of the weather. No specific directions can be given.

The following general rules may be followed with good results in ventilating crowded rooms where the air is not heated before it is brought into the rooms:

1. Introduce air into the room through many small openings instead of a few large ones.
2. Introduce the air at the warmest portions of the room.
3. Provide openings both at the upper and lower parts of the room.
4. If a wind is blowing ventilate principally from the sheltered side of the building.

Additional Observations.

1. Separate the thorax of a small animal (a kitten will answer) from the remainder of the body, leaving uninjured the trachea and diaphragm. Remove skin and examine the intercostal muscles. Note shape and arrangement of diaphragm. Inflate the lungs through trachea and observe change in thorax. Cut through chest wall and note collapse of lung when air enters. Study the pleura finding the partition between the two sides of the thorax.
2. Remove the lungs from a frog. Inflate them and then tie the windpipe to prevent escape of air. Let dry and examine. The human lung is made up of a number of parts, each similar to the entire lung of the frog.
3. Examine the scrapings from the roof of the mouth of a live frog, in a little water, with a compound microscope, for cilia.
4. Observe the respirations of the human body. Determine the number made per minute by the different members of the class, and then find the average.

The Passing of Oxygen Through the Body.

The purpose for which oxygen is introduced in the body is accomplished at the cells. From what has been learned by the study of the blood and lymph, the organs of circulation, and the organs of respiration, the pupil should be able to trace the passage of the oxygen from the outside atmosphere to the cells.

What Oxygen Does at the Cells. At the cells the oxygen unites with the carbon and hydrogen of the compounds in the liquid food and with the cell protoplasm. This uniting goes on all the time, keeping up what has been called, *a continuous series of chemical changes*. Since these changes are brought about by the uniting of oxygen with cell substances the term *oxidation* has been applied to them.

The Chief Results of Oxidation are as follows:

1. *The liberation of energy in the body*, to be used as heat, muscular motion, and nervous action.
2. *The formation of useful substances* which are added to the cell protoplasm, either to take the place of other material or to enable it to grow.
3. *The formation of waste materials*.

The setting free of energy in the body and the formation of materials which may be added to the protoplasm are results of vast importance to the body. They are the conditions necessary to the maintenance of life. Hence oxygen is frequently called the supporter of life. Is it any more a supporter of life than the food materials with which it unites?

Passage of Oxygen From the Body. In serving its purpose in the cells, oxygen ceases to exist as a *free*, or uncombined, element and becomes a part of the substances which it helps to form. Since the great majority of these are finally reduced to waste material, the oxygen finds its way out of the body as a constituent of the waste products. The carbon dioxid, which leaves the body at the lungs, contains a part of it. The waste materials thrown off by kidneys, skin, and liver contain the remainder.

A Comparison. The oxygen which passes through a stove during combustion serves a purpose similar to that which passes through the body. The oxygen in the stove, by uniting with the carbon and hydrogen of the wood or coal, causes the chemical change (oxidation) which is called combustion. The results of the oxidation are the liberation of energy in the form of heat and light and the

formation of compounds, all of which are waste materials. The oxygen enters the stove as a free element and leaves it as a part of the gaseous compounds which pass out through the chimney.

References. On description of respiratory organs, F. and S., 112-117; S., 128-131; C., 104-110; J., 162-166. On respiratory movements, F. and S., 117-123; S., 131-135; C., 113-117; J., 166-169. Interchange of gases at the lungs, F. and S., 108-112; J., 175-179. Quantity of air breathed, F. and S., 124; J., 180. On ventilation, F. and S., 127; S., 140-150; C., 137-142; J., 179-183. On effect of alcohol and tobacco on air passages, S., 137-138. On hygiene of respiratory organs, C., 120. On dangers of breathing dust, C., 142-150.

Practical Questions. 1. What properties of the atmosphere are taken advantage of in the different processes of respiration? 2. Of what advantage is the elasticity of the pleura? 3. How does the air entering the lungs differ in composition from that leaving the lungs? Account for the difference. 4. Trace the passage of the oxygen from the outside atmosphere to the cells. Trace it from the cells to the outside atmosphere. 5. Give three reasons for breathing through the nostrils. 6. What is the special work of the diaphragm in breathing? 7. Why are you unable to expand the chest when the mouth and nostrils are closed? Try it. 8. What effect would an opening in the chest wall have on one's ability to inflate the lungs? 9. Show how active exercise, as running and bicycle riding, tends to develop the lungs. 10. How does compressing the waist interfere with breathing? 11. If 30 cubic inches of air pass into the lungs at each inspiration and .04 of this enters the blood as oxygen, calculate the number of cubic feet of oxygen consumed each day, the number of inspirations being 18 per minute. 12. Find the weight of a day's supply of oxygen as found in the above problem, allowing 1.3 oz. as the weight of a cubic foot of oxygen. 13. In what sense is oxygen a supporter of life? 14. In what different ways is the oxygen of the atmosphere adapted to bringing about the chemical changes in the body? 15. Make a study of the school room with reference to its hygienic ventilation.

CHAPTER VII.

Liberation of Energy in the Body.

What is Energy? Energy is the power which certain bodies have of acting on other bodies. Although there is a great variety of ways in which bodies may act on each other, all such actions are alike in this: There is a *transfer of motion* from the acting body to the body acted upon. This motion may cause a change in the position of the body. It may set into vibration the molecules which compose the body. Or it may agitate the ether which surrounds and penetrates all bodies and fills all space. In any event the transference of motion is known to take place and is the chief evidence of action between bodies. Hence, we may say that *bodies possess energy when they are able to give motion to other bodies.*

Types of Energy. All moving bodies, without exception, are able to communicate motion to bodies against which they strike. Hence, all moving bodies have energy. Do bodies at rest possess energy? We know that a stone held above the earth, a stretched piece of rubber, the powder in a rifle have the *capability* of causing motion within themselves and then of communicating this motion to other bodies. Certainly these bodies possess energy.

Physicists recognize two types of energy. One is that possessed by a body on account of its motion and is called *kinetic* energy. The other is that possessed by a body on account of its position or the condition of its molecules and is called *potential* energy. The first is described as energy *in action*; the second as energy *at rest*.

How Energy Becomes Potential. Much of the potential energy about us is due to the attraction which different portions of matter have for each other. If bodies, having an attraction for each other, are separated, their attraction tends to make them move toward each other. This gives them the capability of motion and accounts for their energy. If we raise a stone above the earth, we give it potential energy, because we place it where gravitation can cause it to move. Stretching a piece of rubber gives it potential energy because it separates the molecules, giving cohesion an opportunity to draw them closer together. Other attractive forces may be taken advantage of in the same way. The following statements are easily proven:

1. Potential energy exists where portions of matter, which attract each other, are separated.
2. Potential energy may be given to bodies by separating them from bodies for which they have an attraction.

Chemical Potential Energy is that which bodies have because of chemism, or chemical affinity. Chemism is the attraction between atoms, the smallest particles found in matter. A body possesses chemical potential energy when its atoms are separated from the atoms of other bodies for which they have an attraction. Gun powder, for example, has chemical potential energy. It is prepared by mixing (not uniting) in correct proportions, sulphur, carbon, and potassium nitrate, or nitre, which is rich in oxygen. The atoms of the sulphur and carbon have a strong attraction for the atoms of oxygen. When the temperature of the powder is raised sufficiently the atoms fly toward each other and unite to form new compounds, causing the explosion.

In the atmosphere is a large supply of free, or uncombined oxygen. (Recall its properties.) On the earth are many substances which contain elements, the atoms of which have a strong affinity for the atoms of oxygen. By complying with certain known conditions a union between these elements and oxygen is readily brought about. Combustion is a result of such a union. It thus happens that the oxygen of the air on the one hand, and the products of plant life, wood, coal, etc., on the other hand, on account of the

mutual attraction of their atoms and their condition of separation, hold in reserve the earth's largest supply of potential energy.

Transformation of Energy. When the separated bodies, in obedience to their attraction, move toward each other, their potential energy is transformed into kinetic. The energy of position or condition becomes energy of motion. The falling of a stone and the burning of wood are alike illustrations of such a transformation.

On the other hand, if kinetic energy is employed to separate bodies which have an attraction for each other, the reverse of this occurs. Kinetic energy is transformed into potential energy. The lifting of a weight, the bending of a bow, and the separation of water into oxygen and hydrogen by electricity, are familiar examples. This process has been called the "storing of energy."

The Work of Plants. Plants transform kinetic into potential energy on a large scale by the separation of carbon dioxide into carbon and oxygen. (See p. 34.) The kinetic energy in this case is the sunlight, and the potential energy which carbon and oxygen have *on account of being separated*, represents the kinetic energy of the sunlight which the plant used in separating them. In doing this, plants store up the energy of the sun for future use.

Forms of Kinetic Energy. In the transformation of energy which takes place when wood burns, two forms of kinetic energy are readily recognized as heat and light. We are sometimes made aware of a third form through the sense of hearing. If the heat is applied to water, steam is produced which, in passing through the cylinder of a steam engine, causes motion of the machinery, and this in turn may cause electrical energy. We have thus suggested the chief forms of kinetic energy, which are heat, light, mechanical motion, sound, and electrical energy. An extended study of energy reveals:—

1. That the different forms of kinetic energy are related to each other in the sense that each is a form of motion,
2. That one form of kinetic energy is readily changed into another form.

3. That energy can neither be created nor destroyed. It can be transferred from one body to another, and changed from one form into another form. It may pass from kinetic into potential, or the reverse, and may become so diffused that it cannot be used by man. Still there is neither loss nor gain of energy—the sum total in the universe remaining always a constant quantity.

The Energy of the Body. The body can communicate motion to its surroundings and can move itself from place to place. These are unmistakable evidences of its energy. Even when the body is perfectly quiet, as regards external things, we have proofs of its energy in the work done in carrying on the vital processes and in the production of heat.

To supply the energy needed by the body is one of the most difficult problems of animal life. The animal cannot create energy; neither can it, like the plant, use the kinetic energy which may come to it from the outside. The energy needed by the body must be taken from the supply of potential energy possessed by the oxygen of the air and the products of vegetation. Accordingly we have introduced into the body through the oxygen which we breathe and the food which we eat, energy in the potential form. This when liberated, or transformed into kinetic energy, is used in doing the work of the body.

Energy is Liberated in the Body through the uniting of oxygen with food substances in the cells. The potential energy, which they have, by virtue of their separation, becomes kinetic energy by their union and as heat, motion, or nervous energy is used by the body.

The energy must be liberated just as it is needed. Hence the oxidations in the cells must be so controlled that their rapidity shall correspond to the demands of the body. The quantity of energy liberated by a certain organ is also under control and is made to correspond to the work which that organ is called upon to perform.

Animal Heat. It is estimated that as much as 5-6 of the energy liberated in the body is in the form of heat, the remainder being used in doing work. The proportion varies with different individuals and in the same person during different seasons of the year.

The heat is used in keeping the body at that temperature which is best suited to carrying on the vital processes. This is about 98° F. and is called the normal temperature. To maintain this temperature uniformly through all the varying conditions within, and on the outside of, the body requires a very delicate adjustment of the heat-producing and regulating processes. All parts of the body through the oxidations taking place within them, furnish heat. Active organs, however, such as the muscles, brain, and large glands furnish proportionally a larger share. The blood in its passage through the body serves as a heat distributor and keeps the temperature about the same in all parts of the body.

One's Capacity for Producing Heat sustains a very important relation to the general health, inasmuch as a sudden chill to the body may result in a number of derangements, the best known of which is that condition called a "cold." In some individuals the capacity for producing heat is so low that the body is unable to respond to a sudden demand for heat, as happens when one goes from a warm into a cold room, and, as a consequence, is unable to protect itself against unavoidable exposures to cold.

Impairment of the Heat Producing Capacity is brought about in many ways. Many of the diseases which attack the body do this directly or indirectly to quite an extent. In health excessive care in protecting the body from cold is perhaps the most potent cause of its impairment. Staying in rooms heated above a temperature of 70° F., wearing clothing unnecessarily heavy, and sleeping under an excess of bed clothes, diminish the power to produce heat, because they accustom the body to producing only a small amount. Lack of physical exercise in the open air as well as too much time spent in poorly lighted and ventilated rooms tend also to diminish it. Since most of the heat of the body comes by the union of oxygen with food materials in the cells, a limited supply of either will interfere with the production of heat.

A knowledge of the ways by which the heat producing power of the body is impaired will suggest the proper methods for preserving and increasing it.

References. On forms of energy, J., 123; F. and S., 8; C., 251, 252. On the source of energy in the body, J., 124. On production of heat in the body, J., 208-210; F. and S., 179-182; C., 132; S., 224-232.

Practical Questions. 1. What is the proof that a body possesses energy? 2. Show that a stone lying against the earth has no energy, while the same stone above the earth has energy. 3. Water is composed of hydrogen and oxygen, which have an attraction for each other. Why then does not water contain potential energy? 4. What kind of energy has a bent bow, a revolving wheel, a coiled spring, the wind? 5. Why is it necessary to separate bodies having an attraction for each other, in order to give them energy? 6. Account for the energy possessed by the oxygen of the air and food substances? 7. How do

plants store the sun's energy? 8. In what different ways does the body expend energy? 9. What is the source of the body's energy? 10. Give directions for increasing one's ability to produce heat.

Simple Experiments. 1. The change of *kinetic into potential energy* (the storing of energy) may be shown by stretching a piece of rubber, lifting a body, separating the armature from a magnet, and by decomposing water with an electric current.

2. The change of *potential into kinetic energy* may be shown by letting bodies fall, releasing the end of a stretched piece of rubber, causing the magnet to attract the armature, and by burning wood.

3. The change of one form of kinetic energy into another form may be shown by rubbing two pieces of wood together until they become heated, by ringing a bell by striking it, and by causing motion in air and water by heating them. If suitable electrical apparatus is at hand the transformation of electrical energy into heat, light, sound, or mechanical motion can easily be shown.

Notes on Energy.

CHAPTER VIII.

Foods.

How Chemical Changes in the Body Differ From Those in a Stove. Much of the material taken into the body is not oxidized at once, but is formed into material which becomes a part of the cell. On the other hand, the protoplasm of the cell unites with oxygen as well as material not a part of the protoplasm. Thus in addition to simple oxidations, like those which take place in a stove, there goes on all the time in the body the double process of *building up and tearing down of tissues*.

Purposes of Food. Food serves two distinct purposes in the body. First of all, it supplies material for the rebuilding of the tissues. In the second place, by uniting with the oxygen, it liberates energy. Any substance which does not serve one or both of these purposes is not food in the true sense. Perhaps the best definition yet offered for food is this: "Food is that which, introduced into the body, builds tissue or yields energy."

Substances Suitable for Food. All substances which contain materials needed for rebuilding tissues cannot be used as food. It is also true that many substances which yield energy outside of the body, are unsuited to supplying energy within the body. In general, materials to serve as food, must conform to the following conditions:

1. They must be capable of reduction to a liquid state or to a finely divided condition, which makes it possible for them to be taken into the body and distributed by the blood to the cells.

2. They must consist of compounds, the affinity of whose elements is weak enough to permit oxygen to unite with those parts for which it has an attraction. In other words, they must be capable of oxidation. This is necessary, both to liberate energy and to prepare material for the tissues.

3. They must be of such a nature that they will not injure the body in their passage through it.

Kinds of Foods. All substances which may be properly classed as foods are obtained from the vegetable and animal kingdoms. The following table shows the more important classes of foods and their sources:

1. Proteids, or Nitrogenous substances	{	Albumen..	{ Found in lean meat and the white of eggs.
		Casein	{ Found in milk and cheese.
		Gluten	{ Found in grains.
		Legumen..	{ Found in beans and peas.
2. Non-nitrogenous substances	{	Fats ..	{ Solid fat { Found in animals.
			{ Oil..... { Found in nuts, olives, grain, etc.
	{	Carbo-hydrates	{ Starch.. { Found in potatoes, rice, grain, etc.
			{ Sugar { Cane .. { Sugar cane, beets, etc.
			{ Grape { Certain fruits.

These are called *organic* foods, because they have been prepared by organized bodies—plants and animals. They are alike in that they contain carbon, hydrogen, and oxygen. The nitrogenous substances, however, contain nitrogen in addition to these. The four elements named form, by far, the greater bulk of all food substances. Other elements, as sulphur, iron, phosphorus, potassium, calcium, and sodium which occur in various foods, are found in minute quantities.

Inorganic Substances, supplied by the mineral kingdom, also find their way into the body, though they are not properly classed as foods. The most important of these are water and common salt.

COMPOSITION OF FOOD MATERIALS. The following table condensed from Atwater's "Foods: Nutritive Value and Cost," published by the U. S. Department of Agriculture shows the percentage of proteids, fat, carbohydrates and mineral matter in the edible portions of the more common substances taken as food:

Food Materials.	Water.	Solids.	Pro- teid.	Fat.	Carbo- hydrates	Mineral mat- ters.	Fuel value of 1 pound.
Animal foods, edible portion.							
Beef:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Cal.
Neck	62	38	19.5	17.5	.....	1	1,100
Shoulder	63.9	36.1	19.5	15.6	.....	1	1,020
Chuck rib	58	42	17.6	23.5	.....	.9	1,320
Rib	48.1	51.9	15.4	35.6	.....	.9	1,790
Sh loin	60.	40	18.5	20.5	.....	1	1,210
Round	68.2	31.8	20.5	10.1	.....	1.2	805
Side, without kidney fat	54.8	45.2	17.2	27.1	.....	.9	1,465
Rump, corned	58.1	41.9	13.3	26.6	.....	2	1,370
Flank, corned	49.8	50.2	14.2	33	.....	3	1,655
Veal, shoulder	68.8	31.2	20.2	9.8	.....	1.2	790
Mutton:							
Shoulder	58.6	41.4	18.1	22.4	.....	.9	1,280
Leg	61.8	38.2	18.3	19	.....	.9	1,140
Loin	49.3	50.7	15	35	.....	.7	1,755
Side, without kidney fat	53.5	46.5	16.9	28.7	.....	.9	1,525
Pork:							
Shoulder roast, fresh	50.3	49.7	16	32.8	.....	.9	1,680
Ham, salted, smoked	41.5	58.5	16.7	39.1	.....	2.7	1,960
Fat, salted	12.1	87.9	.9	82.8	.....	4.2	3,510
Sausage:							
Pork	41.5	58.8	13.8	42.8	.....	2.2	2,065
Bologna	62.4	37.6	18.8	15.8	.....	3	1,015
Chicken	72.2	27.8	24.4	2	.....	1.4	540
Turkey	66.2	33.8	23.9	8.7	.....	1.2	810
Eggs	73.8	26.2	14.9	10.5	.....	.8	721
Milk	87	13	3.6	4	4.7	.7	325
Butter	10.5	89	1	85	.5	.3	3,615
Oleomargarine	11	89.5	.6	85	.4	3	3,605
Cheese:							
Full cream	30.2	69.8	28.3	35.5	1.8	4.2	2,070
Skim milk	41.3	58.7	38.4	6.8	8.9	4.6	1,165
Fish:							
Codfish	82.6	17.4	15.8	.4	.....	1.2	310
Mackerel	73.4	26.6	18.2	7.1	.....	1.3	640
Salmon	63.6	36.4	21.6	13.4	.....	1.4	965
Mackerel, salt	43.4	.....	17.3	26.4	.....	2.6	1,860
Oysters	87.1	12.9	6	1.2	3.7	2	230
Vegetable foods.							
Wheat flour	12.5	87.5	11	1.1	74.9	.5	1,645
Graham flour (wheat)	13.1	86.9	11.7	1.7	71.7	1.8	1,625
Rye flour	13.1	86.9	6.7	.8	78.7	.7	1,625
Buckwheat flour	14.6	85.4	6.9	1.4	76.1	1	1,605
Oatmeal	7.6	92.4	15.1	7.1	68.2	2	1,850
Corn meal	15	85	9.2	3.8	70.6	1.4	1,645
Rice	12.4	87.6	7.4	.4	79.4	.4	1,630
Peas	12.3	87.7	26.7	1.7	56.4	2.9	1,565
Beans	12.6	87.4	23.1	2	59.2	3.1	1,615
Potatoes	78.9	21.1	2.1	.1	17.9	1	375
Sweet potatoes	71.1	28.9	1.5	.4	26	1	530
Turnips	89.4	10.6	1.2	.2	8.2	1	185
Carrots	88.6	11.4	1.1	.4	8.9	1	200
Onions	87.6	12.4	1.4	.3	10.1	.6	225
String beans	78.2	12.8	2.2	.4	9.4	.8	235
Green peas	78.1	21.9	4.4	.6	16	.9	405
Green corn	81.3	18.7	2.8	1.1	13.2	.6	345
Tomatoes	96	4	.8	.4	2.5	.3	80
Cabbage	91.9	8.1	2.1	.3	5.5	1.1	155
Apples	83.2	16.8	.2	.4	15.9	.3	315
Sugar, granulated	2	98	.....	.....	97.8	.2	1,820
Molasses	24.6	75.4	.....	.....	73.1	2.3	1,360
White bread (wheat)	32.3	67.7	8.8	1.7	56.3	.9	1,280
Boston crackers	8.3	91.7	10.7	9.9	68.7	2.4	1,895

Special Uses of Nitrogenous and Non-Nitrogenous Foods.

Both of these classes, on account of their ability to unite with oxygen, are capable of yielding energy. But since all the tissues contain nitrogen, only *the nitrogenous foods are suitable for tissue building purposes.*

On the other hand, the non-nitrogenous foods unite more readily with oxygen, and produce fewer waste materials when they do unite. For these reasons they are especially adapted to liberating energy. In a general way then we may speak of nitrogenous substances as *tissue foods*, and the non-nitrogenous as *energy foods*.

A well balanced diet is one in which these two classes of food are eaten in the proportion in which the body needs them. This proportion varies with the individual and his occupation. In general it may be stated that the body needs about four parts of energy food to one part of tissue food.

Importance of Water. Since water, in passing through the body undergoes no chemical change and yields no energy, it cannot be classed as a food. Yet, next to oxygen, it is probably the most important substance taken into the body. It is present in all the tissues, and forms about two-thirds of the total weight of the body. Its main uses are:

1. To keep the tissues of the body soft and pliable.
2. To dissolve food materials so that they may enter the body and be distributed in the blood to different parts.
3. To dissolve waste materials so that they may be removed from the body by the organs of excretion.
4. To serve as a means of transfer of substances according to the principle of osmosis. (See p. 30.)

The Purpose of Common Salt in the body is not understood. By some it is claimed that it assists in digestion and in the assimilation of material at the tissues. Others have advanced the theory that its wide-spread use is the result of habit. The fact that animals deprived of salt lose in health and general vitality, indicates that it serves some important purpose.

References. On uses of food, S., 17; J., 119. On classes of food, S., 23-40; J., 120; C., 167-170; F. and S., 152-155. On purposes of water, J., 125; S., 19-22; C., 170-173. On purposes of salts, C., 173; S., 18; J., 125.

Practical Questions. 1. Give two differences between the chemical changes in a stove and those in the body. 2. Wood and coal contain energy; why cannot they be used as food? 3. Why are non-nitrogenous foods unsuited to rebuilding tissue? 4. What advantages have the non-nitrogenous over the nitrogenous foods in the liberation of energy? 5. Show that life cannot be carried on in the body without water. 6. Consulting the table on page 57, select four foods which, if eaten at a single meal, will furnish the proportion of tissue and energy material needed by the body.

CHAPTER IX.

Digestion.

Purpose and Nature of Digestion. Digestion is the process by which food material is prepared for the blood. Since nothing but liquids can enter the blood vessels, digestion must consist, to a large extent, of the reduction of solids to the liquid state. This is accomplished by *dissolving* them in certain liquids which are prepared for this purpose by organs called glands.

The condition of the materials acted on and the changes which they undergo are suggested by the following

Experiment: Label three tumblers. In the first, place some water ; in the second, a teaspoonful of fine salt ; and in the third, some pulverized limestone. Note that the contents of the first tumbler is already in a liquid condition. To the second add water and note the result. To the third add water also. If no result follows, add hydrochloric acid, noting what happens. State the changes, if any, which were necessary to reduce the contents of the different tumblers to a liquid state.

1.

2.

3.

The limestone, being insoluble in water, is changed by the acid to calcium chlorid, a substance soluble in water.

The Alimentary Canal in different individuals varies in length from 25 to 30 feet. The greater portion of it is made up of three distinct layers of substance, called coats. (The œsophagus and the pharynx have only two coats.) The inner coat consists of *mucous* membrane, the middle coat is *muscular*; the outer coat is a *serous* membrane, being a continuation of the lining of the abdominal cavity called

Make a sketch showing coats of the canal.



the *peritoneum*. Another coat is sometimes described, called the *submucous*, which lies between the mucous and the muscular.

The Mucous Membrane of the alimentary canal is similar to that found in other parts of the body. This membrane is sometimes spoken of as the inner skin. It is like the outer skin in being made up of two distinct layers. The under layer is the thicker and contains blood vessels, nerves, and glands. The upper layer consists principally of tough, non-sensitive epithelial cells. Mucous membrane lines all the inner cavities that have connection with the outside of the body. It is named from a liquid it secretes called *mucus*, which keeps it soft and pliable.

Complete the sketch showing the different parts of the canal and large glands attached to it.

The mucous membrane presents different appearances in different parts of the alimen-

tary canal. That of the mouth, pharynx, and œsophagus is *smooth*. In the stomach it contains a number of *longitudinal folds* which greatly increase its surface and furnish additional room for the gastric glands embedded within it. In the small intestine it has a *soft, velvety appearance* due to the presence of large numbers of absorbent vessels called the *villi*; and its surface is much increased by transverse folds or ridges. These folds retard the motion of the food through the small intestine and provide more surface for the villi. The mucous membrane of the large intestine resembles that of the stomach, but the folds are smaller.

The Muscular Coat is continuous throughout the entire length of the canal, except the mouth, where its place is taken by the strong muscles of mastication. It presents variations at different places as follows:

1. In the pharynx it is made up of a series of thin overlapping muscles, one above the other. 2. In the stomach it consists of three layers which surround that organ in different directions. 3. In the œsophagus, the small intestine, and the large intestine, the coat consists of two layers, one encircling the canal, the other covering it longitudinally. (The longitudinal layer in the large intestine converges into three narrow bands which, being shorter than the rest of the tube, cause it to be thrown into pouches between them.)

Sketch the stomach, showing the muscles.

Work of the Alimentary Muscles. The mechanical part of digestion is accomplished by the muscles which encircle the alimentary canal. Their chief uses are:

1. To push the food through the canal. This seems to be the main use of the muscles of the pharynx, œsophagus, small intestine, and large intestine.

2. To supply the necessary force for grinding the food. What muscles do this work?

3. To mix the food with different juices. Supply illustrations.

4. To close up the passage at certain places until the digestive processes at those places are completed. This is the function of the muscular bands at the two openings of the stomach.

The regular movements of the stomach and small intestines caused by their muscles, are called the *peristaltic* movements.

Parts of the Alimentary Canal.

Since information concerning the structure and function of the parts of the canal is easily obtained from the usual school text-books on Physiology, only the plan of their study is here indicated.

The Mouth is an irregular cavity at the beginning of the canal. Give three of its uses. Name its boundaries. How is it separated from the pharynx? How may its size be varied to suit its contents? Most of the space within the mouth is usually taken up by the tongue and

The Teeth. The parts of a tooth are the *crown*, the *neck*, and the *fang*. A tooth is made up of *enamel*, *dentine*, *pulp*, and *cement*. Give properties and uses of each substance.

Represent a section of a tooth showing its parts and the position of the different materials composing it.

Show by a diagram the position of the different kinds of teeth in the jaw.

Name, locate, describe, and give use of the different kinds of teeth. What set of teeth is called permanent? What temporary? How many in each set? State two functions of the teeth. Give directions for care of teeth. When should the dentist be consulted?

The Tongue is a muscular organ which has its fibers running in all directions. It is thus able to assume a great variety of shapes. At its base it is connected with the hyoid and submaxillary bones. Name two uses of the tongue.

Represent a longitudinal section of the tongue showing direction of some of its muscular fibers.

Pharynx. This cavity is the *cross roads* of the air tract, and the food canal. It lies back of the mouth and has seven different openings. Name them. (See drawing on p. 40.) How is it separated from the mouth? What is its work in swallowing? Are its muscles voluntary or involuntary?

Oesophagus. What is its length? With what is it connected at upper and lower ends? Describe its coats. Does the food fall from mouth into stomach, or is it forced down? Give proofs.

Stomach. Give its shape, size, location, openings, and coats. Describe its two orifices. Compare with other digestive cavities with reference to size. What glands does it contain? Where do they lie? Describe muscles of stomach? What is their function?

Small Intestine. Name and locate its parts. Give its length and diameter. What coats has it? Describe its mucous membrane. How is so long a tube able to accommodate itself to the cavity in which it lies? What is the *mesentery*? What are its uses?

Large Intestine. Give its length and name its parts. At its beginning there is a sort of pouch, or sac, called the *coecum*, into which the small intestine empties by the *ileo-coecal valve*. At the lower portion the coecum connects with a very narrow tube, called the *vermiform appendix*, which is not only an organ without a function, but is often a source of disease.

Glands.

Glands are found in many parts of the body, their function being to secrete liquids. These liquids serve different purposes, those of the digestive organs being to dissolve the food. The materials which form the liquids are obtained by the glands from the blood, but they are supposed to undergo a change as they pass through the glands. Water is the chief constituent of all gland secretions.

General Structure of Glands. All glands have the same essential parts. These are: 1. A layer of gland or secreting cells. 2. A thin layer of connective tissue, called the basement membrane. 3. A network of capillaries very near the cells. 4. A system of nerve fibres.

The gland cells are the active agents in secreting, the basement membrane furnishes a support for the cells, the capillaries bring a supply of blood near the cells, while the nerve fibers connect the cells with the nervous system which controls their activity.

Kinds of Glands. The parts common to all glands are arranged in different ways, as follows:

1. The gland cells are spread over a smooth surface. This is the simplest arrangement possible and is called a *plain secreting surface*. This arrangement is seen where only a small amount of liquid is needed and there is a large amount of surface to furnish it. As a rule it is found in serous membranes like the pleura and peritoneum. It cannot be employed where a large amount of liquid is needed.

2. The gland cells line simple tube-shaped, or sac-shaped, cavities. This greatly increases the secreting surface and forms two kinds of glands. These, from their shapes, are called *simple tubular* and *simple sacular* glands.

3. The gland cells line tube and sac-shaped cavities which contain two or more divisions. This arrangement still further increases the secreting surface and forms the *compound tubular* and *compound sacular* glands.

4. The gland cells are made to line tube and sac-shaped cavities having a great number of divisions, but all communicating with a

single duct or outlet. This arrangement forms a *true compound* gland and is the most efficient contrivance for removing liquids from the blood.

Show by drawings the structure of the different kinds of glands.

1. 2. 3. 4. 5.

6.

Digestive Glands. The different kinds of glands which secrete liquids to act on the food are the simple and compound tubular and sacular glands and the true compound glands. The sacular and tubular glands lie *in the mucous membrane* of the canal, while the true compound glands are situated a short distance from the canal and connect with it by means of ducts. *Within the canal* the liquids come in direct contact with, and act upon, the food.

Make drawings, showing evolution of glands.

Information concerning the location, structure, and secretions of these glands is easily obtained from the usual texts on Physiology. Only the plan of study is here indicated.

Salivary Glands. Locate and describe the different kinds. Are they simple or compound? Compare them with reference to size. When are they most active? How much saliva is secreted daily by them? Locate the ducts which convey the saliva to the mouth.

Gastric Glands. Where located? Number? Size? How much liquid do they secrete daily? What is it called? To what class of glands do they belong?

Liver. Give its location, size, color, and general structure. How much bile is secreted daily? Where does it enter the canal? The liver, unlike the other glands, is more or less active at all times and for this reason has a reservoir called the *gall bladder* which retains the bile until it is needed for digestive purposes.

Functions of the Liver. The work of the liver is not thoroughly understood. However, most physiologists agree that it has at least three functions:

1. It secretes a liquid which aids in digestion.
2. It removes impurities from the blood.
3. It acts as a storage organ. It stores material by preparing from the substances which come to it through the portal vein, a sweetish solid called *glycogen*. "This is formed during digestion and is stored in the liver, to be gradually transformed, in the intervals of digestion, into grape sugar."

Blood Supply of the Liver. More blood passes through the liver than through any other single organ of the body, excepting the heart and lungs. It receives blood from two sources:

1. From the stomach, intestines, and spleen. Blood is passed from these organs to the liver through the *portal* vein. This blood is loaded with food material recently digested, but it contains no oxygen.
2. From the aorta. This contains oxygen and reaches the liver through the hepatic artery.

In the liver the portal vein and hepatic artery divide and subdivide until they empty into capillaries surrounding the liver cells. The capillaries in turn empty into a single system of veins which unite to form the large *hepatic* vein. This vein empties into the vena cava ascending.

Pancreas. Give its location, size, shape, and general structure. What is its secretion called? How much of this liquid is daily secreted? Where do the ducts from the liver and pancreas enter the intestine?

Intestinal Glands. These are embedded in the mucous membrane of both the small and large intestines and are, for the most part, simple tubular glands. What is their secretion called? How much is there of it?

The Quantity of Digestive Fluids. Calculate the total number of pounds secreted daily by all the glands. This equals pounds. How does this compare with the quantity of solid food taken daily? What becomes of these liquids after they have served their purpose in the canal?

Digestive Processes.

The General Plan of Digestion is to act on the food in different ways, as it passes through the canal, with the final purpose of reducing it to a liquid state. The different processes through which it passes are *mastication*, *insalivation*, *deglutition*, *stomach digestion*, and *intestinal digestion*. Any portion of food not reduced to a liquid by these processes, passes from the canal as waste.

Mastication. Of what does this process consist? By what organs is it accomplished? Why should it be performed slowly and thoroughly? One purpose of mastication is illustrated by the following

Experiment. Pulverize a teaspoonful of salt and place it in one of two tumblers. In the other, place the same amount of coarse salt. Add water until each tumbler is half full and observe in which the salt first dissolves. In which does the water come in contact with the greater surface of salt?

State
results

Since mastication helps reduce the food to a proper condition for swallowing and for the rapid action of the digestive fluids, it is to be regarded as a *preparatory* process.

Insalivation. This process consists in the mixing of the food with the saliva. How does it prepare the food for swallowing? How does it enable us to taste substances? Name two substances which are dissolved by the saliva. The effect of saliva on starch is shown by the following

Experiment. Make a starch paste by boiling a small lump of starch in a half dozen tablespoonfuls of water. (a) Place a few drops of this in a test tube half full of water and thoroughly mix. Add to this three or four drops of a solution of caustic potash and the same amount of a dilute solution of blue vitriol. Boil the mixture and watch for results. (b) Collect a teaspoonful of saliva from the mouth, thin it with a little water, and add two or three drops of the starch paste, thoroughly mixing. . Keep in a warm place for five minutes, then add caustic potash and blue vitriol, as in previous experiment, and heat until the mixture boils. If it turns an orange-red color it indicates the presence of grape sugar.

State results and
conclusions.

The change of starch into grape sugar is brought about by an active agent in the saliva called *ptyalin*. What is the advantage of such a change? This action, however, continues but a short time, as it is checked in the stomach by the gastric juice.

Deglutition, or swallowing, is the process by which food is transferred from the mouth to the stomach. How is it transferred from the mouth to the pharynx? From the pharynx to the stomach? Locate the muscles which do this work. How much of the swallowing process is voluntary?

Stomach Digestion is accomplished by the *gastric* juice. The most important active agents in this liquid are *hydrochloric* acid and *pepsin*. Three results follow the action of the gastric juice:—

1. The action of the saliva on the starch is checked.
2. The globules of fat are released from the cell walls which enclose them. Fat, however, is not acted upon.
3. The *insoluble* nitrogenous food substances, the *proteids*, are changed into *soluble* substances called *peptones*. This is by far the most important work of the gastric juice. It may be illustrated by the following

Experiment. Prepare artificial gastric juice as follows: To a half tumblerful of water add 15 or 20 drops of hydrochloric acid. In this dissolve twice as much pepsin as will lay on the point of a pen knife. (Both the pepsin and the acid are obtained from the drug store.) Place in the mixture the white of a hard-boiled egg, broken into very small pieces. Allow the whole to stand for 24 hours in a place where the temperature is about 98° F. During this time portions of the egg will be dissolved.

Intestinal Digestion is accomplished mainly by the action of the *bile* and *pancreatic* juice.

The bile has only a feeble action upon any of the food substances, but it helps along digestion, indirectly, in different ways.

1. It counteracts the acid of the stomach, giving the food an alkaline reaction which is necessary for the action of the pancreatic juice.
2. It increases the peristaltic action of the intestines by acting as a stimulus to the muscular coat.
3. It retards the decomposition of food in the intestines.

4. It furnishes a large bulk of liquid which serves to move the contents of the intestines readily along.

The pancreatic juice is the most important of the digestive fluids and acts with vigor on *all* classes of foods.

1. It changes starch into grape sugar, completing the work begun by the saliva.

2. It changes proteids into peptones, finishing the work of the stomach.

3. It emulsifies the fats; that is, it breaks them up into very fine particles so that they can be absorbed.

4. It changes a portion of the fats into two soluble substances called *glycerine* and *fatty acid*.

Experiment. 1. Mix a few drops of starch paste with half a test tube full of a solution obtained by soaking a pig's pancreas, chopped fine, in water. Let the mixture stand in a warm place for ten minutes. Then test for grape sugar as in previous experiment. (Pancreatin, obtained from drug store and dissolved in water may be substituted for the solution from the pancreas.)

2. To a little sweet oil in a test tube or small bottle add water and attempt to mix by shaking. Result? Then add a little baking soda and shake again. The oil is broken into very fine particles, forming what may be called an *emulsion*.

Results and
inferences.

Health Suggestions. Different physiologists have suggested the following rules for the care of the digestive organs. Find some reason for obeying each one: 1. Eat slowly and masticate the food thoroughly. 2. Avoid eating between meals. 3. Avoid use of all stimulants, such as alcoholic drinks, tea, and coffee. 4. Take active exercise daily, in the open air. 5. Drink little water during meals, but plenty of water between meals. 6. Boil impure water before drinking it. 7. Eat only wholesome, well-cooked food. 8. Never swallow anything which is not thoroughly masticated. 9. Obey your appetite and do not think too much about what you eat and how you eat it.

Care of the Bowels. The undigested contents of the alimentary canal should be regularly evacuated. When this is neglected a condition known as constipation or costiveness ensues. This is not only a source of great annoyance but is injurious to the health. In most instances it can be avoided by observing the following habits: 1. Have a regular time each day for evacuating the bowels. 2. Drink plenty of water between meals. 3. Eat generously of fruit and such coarse foods as oatmeal, corn bread, etc. 4. Practice such exercises as bring the abdominal muscles into play and knead the abdomen with the hands.—The importance of this recommendation lies in the fact that *weakness of the muscular coat* is frequently the cause of the trouble. It is only through such indirect exercises as those suggested that the tone of the alimentary muscles can be restored.

Do not rely upon patent medicines, pills, etc., as they usually leave the canal in a weakened condition. When necessary consult a physician.

References. On parts of alimentary canal, S., 59-78; J., 131-146; F. and S., 132-151. On the structure of glands, J., 132-134; C., 155; F. and S., 134-136. On the teeth, S., 61-66; J., 135-139; C., 199-202. On functions of liver, S., 76, 77; F. and S., 162. On digestive processes, J., 150-155; C., 206-214. On the effect of alcohol on digestive organs, S., 79-82. On cooking, C., 193; S., 37-39.

Practical Questions. 1. State the purpose of digestion. How does digested food differ from that not digested? 2. Name the different kinds of foods which must be reduced to soluble substances, before being dissolved. 3. What is gained through masticating the food? Why should this process come first? 4. What are the uses of the muscular coat of the alimentary canal? Why should their weakness, through insufficient exercise, interfere with the digestive processes? 5. Describe the arrangement whereby the liquids, secreted by the glands, are brought in contact with the food. 6. Distinguish in structure and location between compound tubular glands and true compound glands. 7. Name organs which are attacked by each of the following diseases: Appendicitis, gastritis, parotitis, and peritonitis. 8. Why should the liver be supplied with blood from two sources? Why is the liver the only gland with a reservoir for its fluid? 9. Where, by what juices, and in what manner are the fat of meats, the white of eggs, the starch of potatoes, salt, and sugar digested?

CHAPTER X.

Transfer of Food Materials.

By digestion the different food materials are reduced to a liquid state—a condition adapted to the needs of the cells. Before they can reach the cells, however, they must be taken in charge by the organs of circulation and become a part of the blood stream. The transfer of liquids from the alimentary canal to the circulation includes two processes, as follows:

1. The absorption of the liquids by minute vessels in the walls of the canal.
2. Their passage along regular channels to the general circulation.

Absorption. In general, absorption means the penetration of a liquid into the small spaces in the body of a solid and is due to the attraction between the solid and the liquid. The conditions under which it takes place along the alimentary canal, bring into play other forces whose action is not fully understood. In the walls of the canal the absorbing vessels are of two kinds, *capillaries* and *lymphatic tubes*.

The Capillaries throughout the entire length of the canal take in liquids, but the greater amount of their absorbing is done at the small intestine. The capillaries absorb *all kinds of liquid material, except the emulsified fats*.

The Lymphatic Vessels are also capable of absorbing, to a small extent, from all parts of the canal, but all of their important work of this kind is confined to the small intestine. Here they have

a remarkable development, forming a system of tubes peculiar to themselves, called

The Lacteals. The lacteals are *special absorbent vessels for the emulsified fats*. The different tubes comprising the lacteals run together, to form larger and larger ones in the mesentery, until they reach the thoracic duct. While they have for their principal function the absorption of fats, they also, to a small extent, absorb other substances.

Absorption at the Small Intestine. By far the greater amount



Make a sketch showing the villi and their absorbing vessels.

of material absorbed from the alimentary canal is taken up at the small intestine. Its great length, small diameter, and the condition of its mucous membrane all combine to adapt it in a remarkable way for the absorption of liquids. Lining the small intestine throughout the entire length are minute elevations, called

The Villi. Each villus is about 1-50 of an inch in length, has a diameter 1-4 as great, and is covered with a layer of epithelial cells.

Finish the drawing showing the two routes from the alimentary canal to the circulation.

Beneath this covering is a fine kind of connective tissue, through

which passes a net work of capillaries. Within the center of the villus is a long, narrow and sometimes branched space which forms the beginning of a lacteal. The capillaries join small veins which connect with the branches of the portal vein. The small lacteals unite to form larger ones which finally connect with the thoracic duct. The villi are so numerous that they give the mucous membrane of the small intestine a velvety appearance.

Two Routes to the Circulation. There are two distinct routes from the alimentary canal to the general circulation. If substances are absorbed by the blood vessels they pass through the portal vein to the liver. From there they go through the hepatic vein to the vena cava ascending, and then to the right auricle.

If they are absorbed by the lacteals they pass to the thoracic duct and through it to the left subclavian vein, then into the vena cava descending, and into the right auricle. Make a drawing showing these routes.

Fill out the blank spaces in Table I, indicating the passage of materials into the circulation.

References. On absorption, F. and S., 132, 149; S., 84-92; C., 217-221; J., 155, 156. On the villi, F. and S., 148; S., 86; C., 224. On the lacteals, F. and S., 148; C., 222. On absorption from the small intestine, S., 87; F. and S., 149. Absorption from the stomach, C., 215.

TABLE I. THE PASSAGE OF MATERIAL INTO THE CIRCULATION.

(TO BE COMPLETED BY THE PUPIL.)

Classes of Foods.	Where Digested?	By what juices?	How Changed?	Absorbed by?	Route to the Circulation.
Proteids					
Fat					
Starch					
Soluble Substances...					
Liquids					

CHAPTER XI.

The Abdomen and Its Contents.

The Abdominal Cavity lies immediately below the thorax from which it is separated by the diaphragm. Its surrounding walls are continuous with those of the thorax, but are less resisting and admit of greater freedom of motion. The spinal column and muscles of the loins form a heavy, supporting structure at the back, while the side and front walls are made up mainly of connective tissue and sheets of muscle. The cavity terminates below in the hollowed out portion of the pelvic bones, which join firmly with the spinal column behind and provide suitable projections for the attachment of the muscular walls in front and at the sides. The abdominal cavity is the largest cavity in the body and contains organs of great importance.

Dissection of the Abdomen. If the class is not too large, a *half grown* cat is perhaps the best specimen available. It may be killed with chloroform in the following manner: Warm a small, tight box, or jar, having a close-fitting lid, by placing it near a stove or fire-place. Put in the cat and place on the lid, but leave a small opening, through which pour 3 or 4 tablespoonfuls of chloroform. Then close the opening and fasten down the lid. In about 12 minutes the cat will be dead.

Before the cat stiffens stretch it on a board and drive a small nail through each foot. The teacher should make a preliminary examination of the abdomen to see that it is in a fit condition for class study. If the bladder is unnaturally distended, its contents may be forced out by slight pressure.

The following materials will be needed during the dissection and should be near at hand. A sharp knife with a good point, a pair of heavy scissors, a vessel of water, some cotton batting, or a sponge, some fine cord, a few tacks, and a hammer.

During dissection, the specimen should be kept as clean as possible. The escaping blood should be mopped up with cotton or a damp sponge. The teacher

should make at least one dissection privately before attempting a class demonstration.

Order of Observations. 1. Cut through the abdominal wall in the center of the triangular space where the ribs converge. From here cut a slit downward to the lower portion of the abdomen and sideward, each way, as far as convenient. Tack the loosened abdominal walls to the board and proceed to study the exposed parts. Observe the muscles in the abdominal walls and the fold of the *peritoneum* which forms an apron-like covering over the intestines.

2. Observe the position of the stomach, intestines, liver, and spleen, and then, by pushing the intestines to one side, find the kidneys and the bladder.

3. Study the liver with reference to location, size, shape, and color. On the underside, find the gall bladder from which a small tube leads to the small intestine. Observe the *portal vein* as it passes into the liver. As the liver is surcharged with blood, care must be taken to prevent cutting it, or its connecting blood vessels.

4. Within the first coil of the small intestine as it leaves the stomach find the *pancreas*. Note its color, size, and branches. Find where it connects with the small intestine.

5. Tie the canal tightly in two places, half an inch apart above the stomach and cut it in two between these places. Likewise tie and cut the rectum. The stomach and intestines may now be removed from the abdominal cavity and studied to better advantage. Examine the *mesentery* and its connections with the intestines. Notice the divisions of the portal vein and the *lacteals* passing through it. Sketch a coil of the intestine and the mesentery attached to it.

6. Find in the center of the coils of the small intestine an elongated, gland-like body. This is the beginning of the *thoracic duct* and is called the *receptacle of the chyle*. From this the thoracic duct rapidly narrows until it becomes difficult to trace in a small animal.

7. Cut away about two inches of small intestine from the remainder. Split it open for a part of its length and wash out its contents. Observe its coats. Place in water and examine the mucous membrane with a lens to find the villi.

8. Study the connection of the small intestine with the large; split it open at this place, wash out contents, and examine the ileo-coecal valve.

9. Observe the size, shape, and position of the kidneys. Do they lie in front of or back of the peritoneum? Do they lie exactly opposite each other?

10. Note the connection of each kidney with the aorta and vena cava ascending by the *renal artery* and *renal vein*. Find a slender tube, the *ureter*, running from each kidney to the bladder. Do the ureters connect with the top or base of the bladder? Show by a sketch the connection of the kidneys with the large blood vessels and the bladder.

11. Separate a kidney from its connections. With a sharp knife split the kidney like a bean. Examine the cavity on the hollow side and note its connection with the ureter. This is called the *pelvis of the kidney*.

12. Note the differences in color between the outer and inner margins of the kidney. Find the little elevations within the pelvis known as the *urinary pyramids*.

1. Draw a curved line to represent the general shape of the abdominal cavity, and indicate the position of the stomach, liver, intestines, spleen, kidneys and bladder.

2. Show by a drawing the shape of the pancreas and its connection with the small intestine.

3. Make a drawing of a coil of the small intestine showing the mesentery and the branches of the portal vein.

4. Show by a drawing the union of the small, with the large intestine.

5. Make a sketch showing the connection of the kidneys with the large blood vessels and the bladder.

Organs of the Abdomen. As shown by the dissection, most of the abdominal cavity is taken up by the organs of digestion—the stomach, large and small intestines, the liver, and the pancreas. Next to these in the amount of space occupied, are the organs for separating and retaining, temporarily, liquid impurities from the blood — the kidneys and the bladder.

The Spleen occupies a position below and to the left of the stomach. The function of this organ is not understood. Its only connection is with blood vessels, and it is spoken of as a blood gland. Since life continues after its removal from the body, its work, whatever it is, is not regarded as of great importance.

The Peritoneum, already referred to as forming the outer coat of the greater part of the alimentary canal, is to the abdominal cavity what the pleura is to the thoracic cavity. It consists of a double membrane, one layer of which lines the walls of the abdomen, while the other folds over the outside of the organs of the abdominal cavity. It secretes a liquid which prevents friction. An extension of the peritoneum which holds the intestines in position is called the *mesentery*.

A Question of Hygiene. The plan of the body demands freedom of motion on the part of the abdominal walls. This is necessary both in bending the trunk and in breathing. Clothing should not interfere with the abdominal movements. Tight lacing prevents natural breathing and robs the trunk of its freedom of motion. Moreover, it breaks down the lower thoracic arch, compresses the liver, and disturbs the natural location of the abdominal organs. Its continued practice leads to serious results.

References. On dissection of the abdomen, C., 195-197; J., 146; F. and S., 13-19. On the peritoneum, F. and S., 20; C., 197. On the spleen, J., 167; F. and S., 163; C., 102.

Practical Questions. 1. What cavities are found in the trunk? Name the important organs found in each. 2. Compare the pleura and peritoneum with reference to structure, general arrangement, and function. 3. Give functions of the abdominal muscles and the diaphragm. 4. How are the abdominal walls held in position? 5. What changes in the shape of the abdomen take place during respiration? Why are these changes necessary?

CHAPTER XII.

Excretion.

Necessity for Excretion. Organs Employed. Excretion is the process of removing waste material from the body. Much of the material, formed by the chemical changes in the cells, is of no use in the body and is produced only that energy may be liberated. Waste material, if left in the body, interferes with its work and in a short time causes death. Its removal is as necessary as the introduction of oxygen and food into the body.

From the cells the waste materials pass through the lymph into the blood. The blood conveys them to the *organs of excretion*, where they are separated and then passed to the exterior of the body. The organs of excretion, named in the order of their importance, are the *kidneys, lungs, skin, and liver*.

The Different Kinds of Waste Materials resulting from the union of oxygen with food substances in the cells and with the cell protoplasm are mainly the following:

1. *Carbon Dioxid*. The natural state of this compound is a gas, but in the body it is found dissolved in different liquids. (Review its properties. See p. 33.)

2. *Water*. Only a small amount of the water discharged from the body is formed in it. Its discharge in large quantities is necessary to the removal of substances dissolved in it.

3. *Urea*. This is a solid, soluble in water, and found in the body dissolved in liquids.

4. *Salts.* These comprise a number of different materials some of which are formed in the body while others, like common salt, enter as a part of the food. They are solids, but must leave the body dissolved in water.

Relation of Waste Materials to Foods. The non-nitrogenous foods, such as sugar, starch, and fat, by uniting with oxygen, form *carbon dioxid* and *water*.

Nitrogenous foods, such as albumen, gluten, etc., by uniting with oxygen form *carbon dioxid*, *water*, and *urea*.

The salts are derived, to some extent, from all classes of foods.

Quantity of Material Removed From the Body. After growth has been attained the weight of the adult varies only slightly from time to time. The tissues are torn down as fast as they are built up, and only minute portions of materials entering the body stay there permanently. *The quantity of material leaving the body must therefore balance the quantity entering it;* and the work done by the organs of excretion must offset the results of absorption at the organs of digestion and respiration. This is estimated for the average individual to be about five pounds daily.

The Kidneys.

The Kidneys are two bean-shaped organs situated in the back and upper portion of the abdominal cavity, one on each side of the spinal column. They weigh from 4 to 6 ounces each and lie between the abdominal wall and the peritoneum. Two large arteries from the aorta, called the *renal arteries*, supply them with blood, while they are connected with the vena cava ascending by the *renal veins*. They remove from the blood an exceedingly complex liquid called

Show by a drawing the connection of the kidneys with the large blood vessels and the bladder.

the *urine*, the principal constituents of which are *water*, *salts of different kinds*, and *urea*. The kidneys pass their secretion to the bladder by two slender tubes, called the *ureters*.

Review notes on the dissection of the abdomen.

Minute Structure of the Kidneys. The structure of a kidney is the same as that of a true compound gland. Its inner substance is made up chiefly of blood vessels and a system of small tubes, called the

Uriniferous tubes. Each tube starts from the outer margin of the kidney in a globular enlargement called the *capsule* which encloses a cluster of capillaries. From here the tube passes toward the open space on the concave side, known as the pelvis of the kidney. Before reaching this place, however, it makes several loops or turns, and connects with other tubes to form larger ones. It is lined throughout its entire length by *secreting epithelial cells* and is surrounded by a network of capillaries. The materials, removed from the blood as it passes through the kidneys, enter the uriniferous tubes and by them are carried to the pelvis of the kidney.

The Work of the Kidneys is divided between the *clusters of capillaries*, at the beginning of the tubes, and the *secreting cells* lining them. The former *separate water* and the *salts dissolved in it*, from the blood, while the latter separate the *dissolved urea*.

Show by a drawing the general arrangement of the uriniferous tubes.

Hygiene of the Kidneys. The work which devolves upon the kidneys may be lessened in two ways:

1. By keeping the skin clean and active. (See excretory work done by the skin.)

2. By avoiding an excess of nitrogenous foods.—What waste materials are formed by the union of oxygen with nitrogenous foods?

Other Organs of Excretion.

The Lungs have already been studied. They are the principal organs for removing carbon dioxid. They also remove small quantities of water and "animal matter." It is the last named impurity that gives air in poorly ventilated rooms its peculiar odor. How prove the presence of carbon dioxid in the breath? How show the presence of watery vapor? (See p. 37.)

The Skin is an organ with many functions and it will be more fully described at another place. Its excretory product is the *perspiration*, or *sweat*, which consists of water with a small amount of urea, common salt, and other substances dissolved in it. It is separated from the blood by the *sweat glands*. Find a description of these in some physiology. The perspiration comes from the skin either as a liquid or in the form of an invisible vapor. When a liquid it is called *sensible* perspiration; when a vapor, *insensible*.

Experiment. Lay the palm of the hand against a cold window pane for a short time. Account for the collection of moisture on the pane. Does this experiment illustrate sensible or insensible perspiration?

The work of the skin is quite similar to that of the kidneys. In reality it does on a small scale what the kidneys do on a large scale. When the kidneys are diseased the skin becomes more active. Why should it? Why should one bathe frequently?

The Liver discharges its impurities in the bile. This liquid has not been studied sufficiently to determine what portions of it are excrementitious and what portions assist in digestion.

Show by filling out the blank spaces in Table II, how the more important waste materials are formed and what organs of excretion remove them.

TABLE II. THE PASSAGE OF THE WASTE FROM THE BODY.

(TO BE COMPLETED BY THE PUPIL.)

	State to which it Belongs.	Form in which it Leaves the Body.	How Formed at the Cells?	The Chief Organs to Remove It.
Carbon Dioxid.....				
Urea				
Water				
Common Salt.....			Common salt is not found at the cells.	

THROWING OFF OF WASTE.

Combined Work of Different Systems.

General Summary. We have seen that the body is an aggregation of different kinds of cells; that it grows by the growth and reproduction of these cells; and that the life of the body, as a whole, is maintained by keeping these cells alive. For ministering to the wants of the cells two liquids (the lymph and the blood) are employed. To keep these liquids in the proper condition for their work in the body, requires the combined action of all the systems which we have studied. The results of their combined work are both direct and indirect.

The Direct Result of the combined action of the systems is to keep up two general movements of materials in the body as follows:

1. An *inward* movement which carries material from the outside of the body toward the cells.
2. An *outward* movement which carries material from the cells to the outside of the body.

Passing inward we have the oxygen and food materials in a condition to unite with each other and thereby change their potential into kinetic energy. Passing outward we have the oxygen and food material *after* they have united at the cells and liberated their energy.

The Indirect Result, of supreme importance, is the keeping up of a *continuous series of chemical changes in the cells*. These liberate energy, provide material for the growth and repair of the tissues, and preserve the life of the body.

Relation of the Systems Illustrated. The relation of the systems to each other and to the cells may be illustrated in the following manner:

With a common center, and with radii of $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{4}$, and $1\frac{3}{4}$ inches, draw four concentric circles. Let the space represented by the first, or inner, circle

represent the cells ; that between the first and second, the lymph ; between the second and third, the blood ; and that between the third and fourth, the systems which have been studied. Write the names in the different circles and indicate by arrows, (1) the flow of material from the digestive and respiratory systems to the cells and (2) the flow of material from the cells to the organs of excretion.

Indicate by filling out the blank spaces in Table III, the passage of the more important materials through the body.

References. On structure of kidneys, J., 203-205 ; C., 163-165 ; F. and S., 166-172 ; S., 151-154. On materials removed by kidneys, S., 153 ; F. and S., 169-172 ; C., 162. On care of the kidneys. S., 154, 155.

Draw a diagram illustrating the relation of the systems.

Practical Questions. 1. What is the necessity for the production of impurities at the cells? 2. Name other functions which certain of the organs of excretion perform. 3. How do impurities get from the cells to the organs of excretion? 4. In what do the uriniferous tubes have their beginning? In what do they terminate? With what are they lined? 5. Bright's disease of the kidneys affects the uriniferous tubes and interferes with their work. What impurity is then left in the blood? 6. Trace urea, water, and salts from where they are removed from the blood through the different tubes to the bladder. 7. Trace carbon dioxid from the cells to the outside atmosphere.

TABLE III. PASSAGE OF MATERIAL THROUGH THE BODY.

(TO BE COMPLETED BY THE PUPIL.)

Materials.	System which Admits it to the Body.	Purposes.	Impurities which it Forms.	Organs which Remove it as Waste.
Proteids				
Fat				
Starch				
Oxygen				
Water.....				

CHAPTER XIII.

The Skeleton.

The Tissues Employed in the construction of the skeleton, or framework of the body, are the osseous, cartilaginous, and connective tissues. These form the bones, supply elastic pads for the ends of the bones, and furnish strong bands, or ligaments, for fastening the bones together. Note that the properties of these tissues adapt them to the purposes which they serve in the skeleton. (See p. 3.)

The Composition of a Bone is indicated to some extent by the following

Experiments: 1. Soak a slender bone, like that in the leg of a chicken, over night in a mixture of one part of hydrochloric acid with four parts of water. Ascertain by bending, stretching, and twisting what properties the bone has lost.

2. Burn a small piece of bone in a clear gas flame or on a bed of coals until it ceases to blaze. By testing, find what properties the bone has lost by the burning.

State
results.
2.

The acid dissolved out the material which gives the bone its property of stiffness. This is called the *mineral matter* and consists chiefly of *carbonate* and *phosphate of lime*.

Burning destroys the material which gives the bone its properties of toughness and elasticity. This is called the *animal matter*. It

consists of connective tissue, walls of blood vessels, nerves, and the protoplasm of the bone cells. About one-third of the bone is animal matter. The other two-thirds is mineral matter.

Gross Structure of Bones.

Observations. 1. Procure a long, dry bone. One that has lain out in a field until it has bleached will answer the purpose excellently. Test its hardness, strength, and stiffness. Saw it in two, a third of the distance from one end and saw the short piece in two, lengthwise. Compare the structure at different places. Find rough elevations on the outside for the attachment of muscles and small openings into the bone for the entrance of blood vessels and nerves. Make drawings to represent the sections.

2. Procure a fresh bone from the butcher shop. Note differences between it and the dry bone. Examine the material covering ends and that which surrounds it. Look for the red and yellow marrow.

1. Drawings of sections of bone.

2. Description of the fresh bone.

The ends of the bone are capped by a layer of *elastic* cartilage while its entire surface is covered by a sheath of connective tissue, called the *periosteum*. In the central part is a long hollow portion, called the *marrow* cavity. This is lined with an inner sheath, the *endosteum*, and is filled with a fatty substance called the *yellow marrow*. Around the marrow cavity, the bone is very dense and compact. At the ends the bone substance is coarse and spongy, containing a great number of small cavities which are filled with the *red marrow*. What is the supposed function of the red marrow?

Minute Structure of Bones. A microscopic study of bone shows two kinds of small canals which penetrate all portions of it. These are known as the *Haversian canals* and

Drawing to show the gross structure of a bone.

the *canaliculi*. The Haversian canals are the larger of the two kinds and, as a rule, run the long way of the bone. Surrounding each canal are several thin, circular layers of hard, bony substance. (Shown by a transverse section of bone prepared for microscopic study.) The canaliculi pass out from the Haversian canals, at right angles, to a great number of irregular clusters in the layers of bone, called the *lacunae*.

Under the microscope the lacunae present an appearance similar to that of a number of large burrs fastened together by their projecting spines. The walls of the lacunae contain the mineral matter of the bone and are,

1. Drawings of sections of bone.

2.

therefore, hard and dense. Within each lacuna is an open space in which lies a soft body, having a nucleus. This is the bone cell, or *bone corpuscle* as it is sometimes called. The work of this cell is to provide for the hardness and stiffness of the bones by depositing mineral matter in the walls surrounding it.

How the Bone Cells Are Nourished. They, like all the other cells of the body, are nourished by the lymph which escapes from the blood. This reaches the cells in different parts of the bone in two ways, as follows:

1. The *cells at the surface of the bone* receive lymph from blood vessels in the periosteum. It reaches them through canaliculi passing from the outside of the bone to the lacunae near the surface.

2. The *cells within the bone* receive nourishment through the channels penetrating the bone. Many of these are large enough to be seen with the naked eye and enclose small veins and arteries. The Haversian canals probably contain capillaries, while the canaliculi convey the lymph.

The Names of the Principal Bones and their grouping in the body are shown by the following table :

I. Axial Skeleton.

A. Skull, 28.	
1. Cranium, 8.	
a. Frontal, forehead.....	1
b. Parietal.....	2
c. Temporals, temples.....	2
d. Occipital.....	1
e. Sphenoid.....	1
f. Ethmoid.....	1
2. Face, 14.	
a. Inferior Maxillary.....	1
b. Superior Maxillaries.....	2
c. Palatine, palate.....	2
d. Nasal bones.....	2
e. Vomer.....	1
f. Inferior Turbinated.....	2
g. Lacrymals.....	2
h. Malars, cheek bones.....	2
3. Bones of the Ear, 6.	
a. Malleus.....	2
b. Incus.....	2
c. Stapes.....	2
B. Spinal Column, 26.	
1. Cervical, or neck vertebrae.....	7
2. Dorsal, or thoracic vertebrae.....	12
3. Lumbar vertebrae.....	5
4. Sacrum.....	1
5. Coccyx.....	1
C. Thorax, 25.	
1. Ribs.....	24
2. Sternum.....	1
D. Hyoid, 1.....	1

II. Appendicular Skeleton.

A. Shoulder Girdle, 4.	
1. Clavicle, collar bone.....	2
2. Scapula, shoulder blade.....	2
B. Upper Extremities, 60.	
1. Humerus.....	2
2. Radius.....	2
3. Ulna.....	2
4. Carpals, wrist bones.....	16
5. Metacarpals.....	10
6. Phalanges.....	28
C. Pelvic girdle, 2.	
1. Os innominatum.....	2
D. Lower Extremities, 60.	
1. Femur, thigh bone.....	2
2. Tibia.....	2
3. Fibula.....	2
4. Patella, knee cap.....	2
5. Tarsals, ankle bones.....	14
6. Metatarsals, bones of the instep.....	10
7. Phalanges, bones of the toes.....	28

If a skeleton can be obtained, it should be studied sufficiently to enable the pupil to locate the different bones and understand the plan and purpose of each group of bones.

The Plan of the Skeleton must be such as to provide a framework for a *moving structure*. Stationary structures are built onto foundations. A moving structure, as a wagon or a bicycle, must have within it some strong, central part to which the remainder is joined. The part of the skeleton to which the other parts are attached is a bony axis made of a number of bones firmly bound together, called the *spinal column*. The head, the ribs, and the pelvic girdle are attached directly to the spinal column, while the other parts are attached indirectly.

Drawing to show plan of the skeleton.

Important Groups of Bones.

Only the plan of study is here indicated. In getting information consult, first of all, the skeleton. After this consult the cuts and descriptions in text-books.

Spinal Column. Give its purposes, plan of construction, length, general shape, and position with reference to the other parts of the body. Study the construction of a single vertebra and the plan of joining it to others. How is the spinal cavity formed? What is its purpose? Where is the cartilage placed? What purpose does it serve? Locate and describe vertebrae, known as the *axis* and the *atlas*. Locate and give number of the *cervical* vertebrae, the *dorsal* vertebrae, and the *lumbar* vertebrae. Locate and describe the *sacrum*.

The Head. Locate and name the bones of the *cranium* and the bones of the *face*. What is the general shape of the bones of the cranium? What important cavity do they enclose? What different purposes are served by the bones of the face? Describe and give function of the *temporal*, *sphenoid*, *inferior maxillary*, and *inferior turbinated* bones.

Ribs. Give number, shape, and functions of the ribs. Describe plan of attachment to spinal column and to the sternum. Distinguish between the *true*, *false*, and *floating* ribs. Why are the ribs placed in a slanting position? What is the main purpose of the ribs?

Pelvic and Shoulder Girdles. Give general purposes of each and describe the bones which form them. Compare them with reference to the number and size of their bones, connection with spinal column, strength of parts, and their uses. (The *pelvic arch* is the strongest arch in the body.)

The Humerus and the Femur. Locate them and name the bones with which they join. Study the joints formed by their articulation with other bones. Compare them with reference to length, shape, strength, and purpose in the body.

Bones of the Forearm and Lower Leg. Name and locate these bones. Study the joints formed by their articulations with other bones. Compare the two groups with reference to size, shape, and strength of bones. What bone in the lower leg, has no corresponding bone in the forearm? What joint in the forearm has no corresponding joint in the lower leg?

Carpal and Tarsal Bones. Locate and give general use of these groups. Compare with reference to position, number, and shape of bones and strength.

Metacarpal and Metatarsal Bones. Locate and give general use of the groups. Compare them with reference to the size, shape, strength, and number of their bones.

Upper and Lower Phalanges. Locate and give general use of these groups. Compare them with reference to the number, size, and shape of their bones. Account for the superior development of one group over the other.

Size and Shape of Bones. The bones vary in shape and size to suit their position and use in the body. Some bones, like the humerus, are adapted to giving form, strength, and stiffness to parts of the body. Others, like the pelvic bones, are fitted for supporting and protecting. Others still, as the wrist and ear bones, are adapted, by their size and shape, to giving a peculiar kind of motion. Where is the smallest bone in the body? Where is the largest? Why should the skull bones and the ribs be flat? Why should the femur, and the humerus, be long and cylindrical? Why should the bones of the wrist be short and rounded?

Articulations.

Any place in the body where two or more bones are joined together is called an articulation. Articulations are of two kinds, known as the *movable* and the *immovable*. A great number of the latter are to be found in the skull where projections from one bone interlock with those of another, the tissue between being very thin. This kind of an articulation is called a *suture*. (Examine bones of a skull.)

A joint is a *movable* articulation. It must be so constructed that the bones glide over each other easily and with-

Show by a drawing the plan of a joint, naming parts.

out friction. The parts of the bones which help to form joints are smooth and are covered with a thick layer of cartilaginous tissue. This serves as an elastic cushion to deaden shocks. The cartilage is covered with the *synovial* membrane, the inner surface of which secretes the *synovial fluid*. What is the purpose of this fluid? It is retained in the joint by the synovial membrane, which surrounds the ends of the bones and extends from one to the other so as to form a closed sac. Strong ligaments join the bones together. The fibers of the ligaments are interwoven with the periosteum, making a very secure attachment. In some cases the ligaments form one continuous sheath around the joint, making what is called a *capsular* ligament. Give an example.

Observation. Procure from the butcher shop the joint of some small animal (hog or sheep). Cut it open and locate the cartilage, synovial membrane and ligaments. Observe the smoothness of the rubbing parts and the strength of the ligaments.

The Different Kinds of Joints are the *ball and socket*, the *hinge*, the *pivot*, and the *combination* joint. The *ball and socket* joint consists of a ball-shaped end of bone which fits into a cup-shaped cavity, called a socket. Name examples. This joint admits of motion in what directions? In the *hinge* joint the bones are grooved and fit together something after the plan of a hinge. Name examples. Of what motion is it capable? The *pivot* joint is formed by one bone rotating or turning against another. Give examples. This joint admits of motion around a given axis. Where a joint combines the motion and structure of some of the above joints it may be called a *combination* joint. Give examples.

The Bones as Instruments of Motion.

In many different ways the bones are valuable aids to the muscles in the production of motion. They do their most important work in this respect by acting as levers.

A Lever may be described as a stiff bar which is used in lifting weights. It is made to turn on a fixed point of support called the *fulcrum*. The force applied to the bar is called the *power*, and that which is lifted is termed the *weight*. Levers are of three kinds,

known as the *first* class, *second* class, and *third* class. The only difference between them is in the position of the power, weight, and fulcrum. In the *first* class the *fulcrum* is *between* the power and weight. In the *second* class the *weight* is *between* the fulcrum and the power. In the *third* class the *power* is *between* the fulcrum and weight.

The distance between the fulcrum and the power is called *the arm of the power* and the distance between the fulcrum and the weight is called *the arm of the weight*. This applies to all the classes of levers.

Represent by drawings the different classes of levers, naming the parts, and showing in each the arm of the power and the arm of the weight.

Uses of the Lever. In a mechanical sense the lever has two important uses:

1. To enable a small power acting through a long distance to move a great weight through a short distance.
2. To enable a great power acting through a short distance to move a small weight through a long distance.

Whether it does the one or the other, depends upon the relative lengths of the lever arms. *The weight will be as many times greater than the power as the power's arm is times longer than the weight's arm, and the distance moved by the weight will be as many times greater than the distance moved by the power as the weight's arm is times longer than the power's arm.*

Experiment. With a stiff, wooden rod, a small weight, a hand scale, and a suitable fulcrum illustrate the foregoing uses of levers. By placing the power and weight at suitable distances from the fulcrum, prove the relation which the power and weight sustain to the lever arms.

A third use of the lever is to enable a power acting in one direction to cause the weight to move in an opposite direction.

Levers in the Body. In the body the muscles furnish the power; a part of the body itself, or some object to be lifted, serves for the weight, and the fulcrum is generally at a joint. Find in the body a representative of each of the three classes of levers. To which class do most of the levers of the body belong? How does the length of the arm of the power compare with the length of the arm of the weight?

Levers serve two main purposes in the body:—1. They enable muscles acting in one direction to move parts of the body in the opposite direction. 2. They enable the muscles acting with great force through short distances to move portions of the body through long distances.

The contraction of the longest muscles does not amount to more than two or three inches, yet they are able, by the use of levers, to make portions of the body move as many feet. Furnish illustrations of this fact.

On the Care of the Bones. What is the danger of having children walk at too early an age? Why should children not sit on seats too high for their feet to reach the floor? Why is moderate exercise beneficial, and violent exercise injurious to the bones? How is a broken bone "set?" What is a sprain? What is a dislocation? Why must a sprain have careful treatment?

References. On the structure of bone, F. and S., 59-63; J., 56-58; S., 156-163; C., 352-354. On the skeleton, F. and S., 36-46; J., 42-51; S., 164-173; C., 346-352. On joints, F. and S., 47-53; J., 59-61; S., 173-177; C., 24-27. On levers, F. and S., 70-75; J., 72, 73; C., 21-23. On care of the bones, S., 163; C., 355. On dislocations and sprains, J., 61, 62; S., 359; C., 355.

Practical Questions. 1. How many bones in the body? What different purposes do they serve? 2. Show that each bone is adapted by its size, shape, and strength, to the use made of it in the body. 3. Locate the bone cells. What is their use in the bone? 4. What is the necessity for the animal matter in a bone? For the mineral matter? 5. What is the mechanical advantage of having certain bones hollow? 6. Give the use of the periosteum. 7. State the purpose of the Haversian canals. Of the canaliculi. 8. What part does the spinal column play in the plan of the skeleton? 9. What purposes are served in the body by the use of levers? 10. Why is it easier to hold a heavy weight straight out from the shoulder, if placed at the elbow than if held in the hand? 11. Name the different materials used in the construction of a joint, and the purpose served by each.

CHAPTER XIV.

The Muscular System.

Muscular Tissue forms nearly one-half of the entire weight of the body. This fact in itself indicates the importance of the problem of supplying the body with the power of motion. Muscular tissue is able to cause motion through its property of contractility. This property enables the tissue, when stimulated, to become shorter and thicker (a condition called contraction) and when the stimulus is removed, to return to its former condition of relaxation.

Most of the muscular tissue in the body is organized into working groups, called muscles. The muscles are of two general types—the *striated* and the *non-striated*.

Note. The reddish muscle found in a piece of beef is a good example of striated muscle, while the clear muscle surrounding the intestine of the cat (p. 78) represents non-striated muscle.

Structure of Striated Muscles. The unit of structure of striated muscular tissue is the *muscle fiber*. This is a slender, thread-like structure, varying in length from $\frac{1}{3}$ to $1\frac{1}{2}$ inches and tapering to a point at each end. Its sides are marked by a great number of dark, transverse lines, called *striations*. The outside part consists of a thin wall, which encloses a semi-liquid material, known as *muscle protoplasm*, which is the contractile part of the fiber. Connected with the muscle fiber near its center is the minute termination of a nerve fiber.

The nature of the muscular fiber is not fully understood. By some physiolo-

gists it is regarded as a single cell; by others, as a collection of many small cells. The weight of evidence seems to be in favor of regarding it as a single cell.

In the long muscles a number of fibers may be joined to form muscle threads. A number of these threads form a slender bundle, around which is placed a thin layer of connective tissue. These bundles are again bound into larger ones by bands of connective tissue, so that the entire muscle consists of *bundles of bundles* of muscular threads. The whole is surrounded by a single sheath of connective tissue called the *perimysium*. At the ends the muscles are attached to *tendons* which connect them with the bones.

Observation. Examine the structure of a piece of beef which has been boiled for a considerable length of time. Separate into the small bundles which make it up. If possible separate one of the smallest bundles into its fibers.

Structure of Non-Striated Muscle. The cells of non-striated muscles differ from the fibers of striated muscles in being shorter, and decidedly spindle-shaped, and in having a single well-defined nucleus. Furthermore, there is a lack of striations, the surface being smooth, and the connection with nerve fibers is less marked.

In the formation of non-striated muscles the cells are interwoven to some extent and held in place by a cementing material. They form thin sheets or bands which surround the organs on which they act.

General Differences Between the Types of Muscles.

1. The striated muscles are under control of the will; the non-striated are not. Find exceptions. 2. The striated are reddish in color; the non-striated are light and pale. 3. The striated are usually attached to the bones of the skeleton which they move as levers; the non-striated surround hollow cavities and tubes, such as the stomach and arteries. 4. The striated muscles contract and relax quickly; the non-striated, slowly. 5. In shape the striated are inclined to be rounded; the non-striated are thin and sheet-like.

Make drawings representing muscle fibers and cells.

Muscular Stimuli. The natural condition of a muscle is that of relaxation. *It is made to contract* by the action of some force upon it. That which acts upon a muscle to cause it to contract is called a *stimulus*. All the muscles of the body are controlled by the nervous system which furnishes a stimulus known as the *nervous impulse*. This originates in the nerve centers and reaches the muscles through the nerves. It will receive further study in connection with the nervous system.

Experiment. Remove the skin from over the large muscles in the leg of a live, brainless frog. (See Appendix.) Wet a piece of rock salt and rub it against the muscle, noting what happens. Then pass a weak current of electricity through the muscle. Finally, by separating the muscles, find a white cord (a nerve) and cut it in two, leaving the end nearest the muscles accessible. Irritate the nerve by pinching or by passing a current of electricity through it, noting results.

State results.

Hot and cold objects, electricity, many kinds of chemicals, and mechanical irritation can all cause muscular contraction and may, therefore, be called muscular stimuli. In the body, however, the nervous impulse is the only stimulus employed.

Liberation of Energy in Muscles. The chief evidences of the liberation of energy at the muscles are *the results which accompany their contraction*. Careful experiments show that, during the contraction period, oxygen and food material are consumed, waste materials such as carbon dioxid and urea are produced, and heat is liberated.

The blood supply to the muscles is also such as permits of materials being carried rapidly to and from the muscles. Blood vessels penetrate them in all directions and the capillaries lie very close to the individual cells. Provision is also made, through the nervous system, whereby the flow of blood in a muscle is increased when it is at work.

From these things, as well as from the great force with which the muscle contracts, we may conclude that the muscle is a *transformer to energy*—that within its protoplasm the chemical changes take place whereby the potential energy of oxygen and food materials is converted into the kinetic energy of motion.

The Plan of Using Muscular Force in doing the work of the body is interesting from a mechanical, as well as physiological standpoint. Muscles exert force *only when they contract*. They can *pull* but not *push*. Hence in the body each muscle must work against some force which produces a result directly opposite to that of the muscle when it contracts. Some work against the elasticity of certain parts of the body; others, to some extent, against gravity; and others, against pressure. But in most instances

Muscles Work Against Muscles. The muscles of the skeleton are arranged after this plan. As a rule, a pair of muscles is so placed, with reference to a joint, that one moves a part of the body in one direction, while the other moves it in the opposite direction. With reference to the work which they do, skeletal muscles are classed as follows:

1. Flexors and extensors. 2. Adductors and abductors. 3. Rotators. 4. Radiating and sphincters.—These are arranged in pairs, the members of which give the different parts of the body their opposing movements.

The flexors and extensors bend and straighten joints; the adductors and abductors draw the limbs toward and away from the axis of the body; the rotators (two kinds) twist and untwist joints; the radiating and sphincters open and close natural openings. Find examples of each of these different classes of muscles.

Tendons are the strong cords of connective tissue which attach the muscles to the bones. The white fibrous tissue of which they are composed is interwoven with the perimysium of the muscle at one end and the periosteum of the bone at the other, making, in this way, a very secure attachment. Are tendons elastic or inelastic? Why?

Work of the Non-Striated Muscles. The motions of the body which are directly concerned in maintaining

Show by a drawing the attachment of the biceps muscle to the bone.

life are brought about by non-striated muscles. The most important of these are the motion of the respiratory and digestive organs, and the changes in the size of the arteries. Why should such important movements be involuntary?

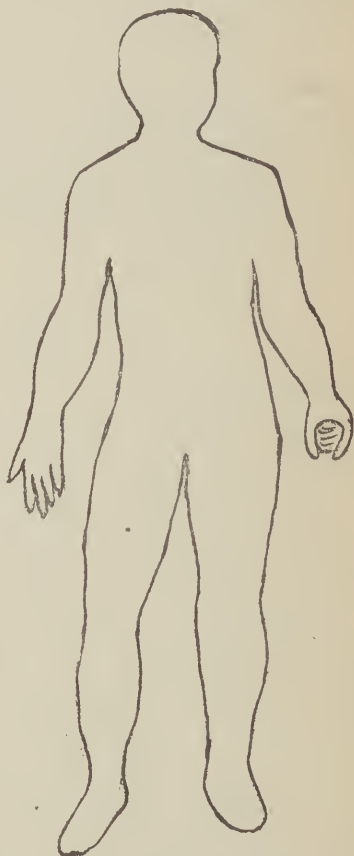
Important Muscles. There are nearly 500 separate muscles in the body. These vary in size, shape, and plan of attachment, to suit their special work in the body. Some of those prominent enough to be distinguished from the outside of the body are as follows:

1. *Of the Head:* the *temporal*, in the temple, and *masseter*, in the cheek. These are attached to the lower jaw, and are the chief muscles of mastication. *Of the neck:* the *sterno-mastoid*, which pass between the base of the skull and the sternum. They assist in turning the head. *Of the arm:* the *biceps*, on the front side, the *triceps* behind, and the *deltoid*, above and beyond the projection of the shoulder. The deltoid lifts the arm. *Of the forearm:* the *flexors* of the fingers, on the under side, and the *extensors* of the fingers, on the upper side. *Of the hand:* the *adductor pollicis* between the thumb and other part of the hand. *Of the trunk:* the *pectoralis major*, between the upper front part of thorax and the shoulder, the *trapezius*, between the back of the shoulder and the spine, the *rectus abdominis*, passing over the front of the abdomen from above downward, the *erector spinae*, found in the small of the back. *Of the leg:* the *gastrocnemius*, the large muscle in the calf of the leg.

* This is the largest muscle in the body, and connects with the heel bone by the tendon of Achilles.

The Necessity for Exercise.

The body is designed for motion and any perversion of its plan means disease. Let the ambitious student, and others of sedentary habits, remember that nearly half of the entire weight of the body is muscular tissue. If physical



Indicate in the cut the position of large muscles, giving names.

exercise is neglected the muscles begin a slow process of degeneration which results in their becoming weak, soft, and flabby. In this condition they contract with little force and tire with slight exertion:

But the worst effects of neglected exercise are to be observed on other portions of the body. The circulation is diminished in force, the blood loses large numbers of its red corpuscles, the breathing capacity is lessened, the excretion of waste is retarded, appetite fails, power to resist disease is diminished, and energy for both mental and physical work is lacking. In brief, one may become a helpless invalid simply by neglecting to take a sufficient amount of physical exercise.

References. On structure of muscles, S., 181-183; F. and S., 64-67; J., 68-70; C., 14-16. On muscular contraction, S., 184-186; F. and S., 67-69; J., 70-71; C., 17. On the heart muscle, F. and S., 67. On muscle and nerve, C., 12-14; J., 69; F. and S., 69. On muscle fatigue, J., 72. On necessity for exercise, S., 191-197; J., 75-77; C., 234-240. On effect of alcohol on muscles, S., 197-201.

Practical Questions. 1. How does the muscle cause motion in the body? 2. If muscles could push as well as pull would so many be needed in the body? Why? 3. Locate a muscle which works against elasticity. One which works against pressure. One which works, to some extent, against gravity. 4. How does the nervous system control the muscles? 5. Give differences in structure between the striated and the non-striated muscles. 6. Give general uses of the striated muscles in the body. Of the non-striated. 7. Show how muscular contraction aids in the circulation of the blood and the lymph. 8. What are the proofs of the change of potential into kinetic energy during muscular contraction? 9. What are the peculiarities of the heart muscle? 10. What results follow a lack of sufficient exercise? 11. What precautions should be observed in taking exercise?

CHAPTER XV.

The Skin.

Protective Coverings. Three kinds of coverings are employed for the protection of the body. These are the *skin*, the *mucous* membrane, and the *serous* membrane. The mucous membrane has already been studied. (See p. 62.) The pleura and peritoneum afford good illustrations of serous membrane. (See pp. 42, 80.)

The skin covers the entire outside of the body, and consists of two layers:—the *dermis*, or true skin, and the *epidermis*, or cuticle.

The Dermis is the under and thicker layer of skin and is made up mainly of a *dense network of connective tissue fibers*. This gives to the skin its toughness. Interwoven with the connective tissue, are numerous *blood vessels*, *lymphatics*, *oil glands*, *perspiratory glands*, and *nerves* which terminate in small bulb-shaped organs called *touch corpuscles*.

At its outer surface, the dermis is exceedingly rough and uneven, forming numerous elevations called the papillae. Each papilla contains the loop of a capillary vessel and a nerve fiber, and many of them are crowned with touch corpuscles. The inner surface of the dermis is attached to the parts beneath by a loose network of connective tissue.

The sebaceous, or oil, glands are situated at the roots of hairs. The oil which they secrete keeps the outside of the skin soft and pliant.

A perspiratory gland consists of a single slender tube which passes through the epidermis and terminates in a rounded coil in the dermis. It is lined with a single layer of cubical cells and is sur-

rounded in the dermis by a network of capillaries. It secretes the *perspiration*, or sweat. The perspiratory glands are exceedingly numerous.

Observation. Examine the palm of the hand with a hand lens. Note the small ridges which correspond to the papillae beneath the cuticle. In these ridges find small pits, the openings of the sweat glands. By counting the number of these on a quarter of an inch of surface, estimate the number on the entire palm of the hand.

Make a sectional drawing illustrating the structure of the skin, naming the parts.

The Epidermis, or cuticle, is much thinner than the dermis. It is tough, non-sensitive, and in some places, rough and hard. It contains no blood vessels, nerves, or lymphatics. Its purpose is purely protective.

Observation. Examine the cuticle of the hand. Where is it thickest? Account for the difference in thickness at different places. Pick a thick portion of it with a pin to see if pain is felt. Inference.

State

results.

The cuticle grows by the multiplication of cells at its under surface. These receive nourishment through the lymph coming from the blood vessels in the dermis. At the inner surface the cells of the cuticle are full and round, while at the outer surface they are flat and scaly.

Where the cuticle joins the dermis is a layer of *pigment*, or color cells, which gives the color to the skin.

The Hair and Nails are modifications of the cuticle.

A hair is a long, slender cylinder of epidermis. It grows from a kind of pit in the dermis, by the addition of cells to its inner end. Give uses of the hair.

The nails are composed of a number of hard, flat, epidermal cells. They grow in length by the addition of cells to their roots and in thickness, by the addition of cells to their under surface. That part of the dermis from which the nails grow is called the *matrix*. Of what use are the nails?

Observation. Examine a finger nail. Is the edge or root the thicker? Account for the difference. What is a proof that the nails are not sensitive?

Functions of the Skin. The skin has the following functions:

1. *Protection.* This is its main function and is provided for through the connective tissue in the dermis, the tough, non-sensitive cells in the epidermis, and the touch corpuscles and their connecting nerve fibers.
2. *It is an organ of excretion.* (See p. 84.)
3. *It is an organ of absorption.* The small blood vessels and lymphatics absorb liquids to a small extent.
4. *It is an organ of touch*, or feeling. This function is provided for through the touch corpuscles and their nerve fibers.
5. *It assists in regulating the temperature of the body*, i. e., in keeping the body from getting too hot or too cold.

How the Skin Regulates Temperature. *It assists in keeping the body warm* by preventing the escape of heat from the body. In

the under portion of the dermis there is considerable fat. This is a poor conductor of heat and acts as would a layer of clothing to keep the heat within the body.

The skin assists in cooling the body in two ways:

1. By the radiation of heat from its surface as from a stove.
2. By the evaporation of the perspiration.

Experiments. 1. Wet the back of the hand with water and move it through the air to hasten evaporation. Observe that as the hand dries, a sensation of cold is felt. Repeat the experiment, using alcohol or gasoline instead of water and noting difference in the effect. Alcohol and gasoline evaporate faster than water.

2. Wet the bulb of a thermometer with alcohol or water. Move it through the air to hasten evaporation. Note and account for the action of the mercury.

State
results.

The above experiments prove the principle that *a liquid, in changing to a gas, absorbs heat*. The perspiration in evaporating, or changing from a liquid to a gas, absorbs heat from the body, making it cool.

The Control of the Heat Producing and Regulating Processes is given over to the nervous system. This system controls the temperature of the body principally through its control over the circulation, the glands in the skin, and the chemical changes in the body. By varying the activity of different places and by shifting the circulation the temperature of the body is kept always at about 98° F.

A fall in temperature in the body is prevented

1. By diminishing the circulation in the skin and increasing it in the internal organs.

2. By diminishing the secretion of perspiration.

3. By increasing the chemical changes in the cells, thereby increasing the amount of heat generated in the body. (See p. 52.)

A rise of temperature in the body is prevented

1. By increasing the circulation of blood in the skin, bringing more heat to the surface, where it can be radiated.

2. By increasing the amount of perspiration.
3. By diminishing the rate of chemical changes at the cells.

Alcohol, by interfering with the nervous control of the circulation causes heat to be wasted at a time when the body should be saving it. If taken on a cold day, it *increases* the circulation in the skin and causes a *feeling of warmth*. This fact has given rise to the erroneous idea that alcohol may act as a heat producer in the body.

The Hygiene of the Skin is nearly all included in the problems of keeping it warm and clean. It is kept warm by *clothing*. *Bathing* is the method of keeping it clean.

Hygienic clothing should be warm and loose fitting. Woolen clothing is generally preferred to cotton because, being a poorer conductor of heat, it affords better protection from cold. But woolen clothing fails to absorb the perspiration rapidly from the skin and pass it to the outside where it is evaporated. This, together with its tendency to irritate, makes it objectionable for wearing next to the skin. If cotton clothing is worn between the woolen clothing and the skin, these difficulties are obviated.

One should bathe often enough *to keep the body clean*. This will depend upon the season, the occupation of the individual, and the nature and amount of the perspiration. As to the kind of bath to be taken and the precautions to be observed, no general directions can be given. These must be determined by the health and natural vigor of the bather. Care must be exercised at all times, however, in preventing too great an exposure of the body, during the bath.

References. On structure of the skin, F. and S., 173-178; S., 202-210; C., 151-156; J., 194-197. On functions of skin, C., 157; J., 198. On glands of skin, F. and S., 176; S., 207, 214; C., 154-156; J., 197. On the hair and the nails, F. and S., 178; S., 211-214; J., 201. On regulation of temperature, C., 157-161; J., 199; F. and S., 181. On clothing, S., 219-222; C., 160. On bathing, S., 215-219; C., 233; J., 203. On effect of alcohol on regulation of temperature, S., 230-232.

Practical Questions. 1. Compare the dermis and epidermis with reference to thickness, composition, and functions. 2. To what is the color of the skin due? How is color affected by sunlight? 3. What different kinds of epidermis are found on our bodies? What kinds on the body of a chicken? 4. Show what provision is made for each of the different functions of the skin. 5. How does perspiration cool the body? 6. How does alcohol make one *feel* warm when he is *losing* heat? 7. What precautions should be observed, by one in poor health, in taking a bath?

CHAPTER XVI.

General Structure and Function of Nervous Tissue.

Nervous Tissue is of two varieties. These, on account of their color, have been designated the "gray matter" and the "white matter." Both are soft, weak, inelastic and, to the naked eye, appear as structureless masses. The microscope, however, shows them to be organized into cells which have long, thread-like attachments, called fibers.

Important Properties of Nervous Tissue. Nervous tissue possesses in a high degree the *property of irritability*. This property refers to the ability of a substance to respond to an external stimulus, and is illustrated by the contraction of muscles, following the application of electricity. Nervous tissue is so delicately organized that the least disturbance from without is sufficient to excite important chemical changes within. The result of these chemical changes is to liberate a peculiar form of energy which is called *nervous force* or *nervous energy*. The nervous tissue as organized in the body is also able to transmit this energy from the place where it is liberated to where it is to be used. Irritability and the power to liberate and transmit nervous energy adapt nervous tissue to the different purposes which it serves in the body.

The Nerve Cell has the usual parts of a complete cell (name them), but differs from all the other cells of the body in having its protoplasm extended, at one or more places, to form the central part of the nerve fiber. The nerve cells found in different parts of the body, differ greatly in size and shape.

■

Nerve cells do not exist singly in the body but are found in groups. A single group of nerve cells is called a *ganglion*. The brain and the spinal cord are great collections of ganglia.

The function of nerve cells is to act as generators of nervous energy. If a number of nerve cells act together for a common purpose, they form a *nerve center*.

The Nerve Fiber is a slender filament or thread of nervous matter, leading off from the nerve cell and *connecting it with some part of the body*. Every fiber contains a central part which is a continuation of the protoplasm of the nerve cell and is called the *axis cylinder*. In most fibers the axis cylinder is surrounded by two other parts, an outside coat, called the *primitive sheath*, and a middle layer of oily substance, called the *medullary sheath*. These are called *medullated* nerve fibers. Those consisting of only the axis cylinder are called *non-medullated* fibers.

The function of nerve fibers is to *transmit* nervous energy from one part of the body to another. This work is done wholly by the axis cylinder, the purpose of the other two coats being to protect the axis cylinder and to prevent the escape of the nervous energy from it. In this respect the primitive sheath and medullary layer serve a purpose similar to the coverings around an electrical wire and may be said to "insulate" the axis cylinder.

Drawings to show the connection of the nerve fiber with nerve and muscle cells, and the structure of a nerve.

The nerve fibers do not extend singly through the body, but are collected into *bundles*. A bundle of nerve fibers is called a *nerve*. The largest nerve of the body is found in the thigh and is called the *sciatic* nerve.

Relation of the Nerve Cell and the Nerve Fiber. The nerve cell and the nerve fiber may be regarded as two parts of the same thing. In their growth, the cell forms first and the fiber grows out from it toward that with which it is to make connection. The "gray matter" appears to be the true nerve substance, being able both to originate and to transmit nervous energy. The "white matter" insulates and protects the "gray matter." In nerve cells the gray matter predominates, giving them a grayish color. In the medullated fibers the white matter is in excess, causing them to have a whitish appearance.

The Nervous Impulse, or nerve current, is a form of nervous energy which passes over the nerve fiber from one part of the body to another. Its nature is not understood. Some physiologists look upon it as a sort of wave motion which is started in the nerve cell, by chemical action, and which travels out, through the protoplasm of the fibers, to the different parts of the body. *The impulse is the means, employed by the nervous system for communicating between and controlling different parts of the body.*

Kinds of Nervous Impulses. When sent out over nerve fibers to organs in different parts of the body the impulses are able both to throw them into action and to check their action. Impulses which throw inactive organs into action, or quicken the action of those already at work, are called *excitant* impulses. Those which check altogether, or diminish, the action of working organs are said to be *inhibitory*. Supply illustrations.

Connections of Nerve Fibers. One end of every nerve fiber is, of course, connected with *its own* nerve cell. The other end will be connected with that part of the body into which the cell is to discharge its impulse. This may be some non-striated muscle, such as is found in the arteries, or digestive organs. It may be in one of the many different kinds of glands or nerve centers. Then,

again, it may find its way to one of the striated muscles. The different fibers are named according to their connections and the direction and nature of the impulses which they transmit.

The Different Kinds of Fibers are shown by the following table :

Nerve Fibers..	{ Afferent	{ Sensory	{ Excitant Inhibitory
		{ Excito-motor	
	{ Efferent	{ Motor	
		{ Vaso-motor	
		{ Secretory	
	{ Intercentral	{ Excitant	
		{ Inhibitory	

Those fibers which connect with special sense organs at the *outside* of the body, and which convey impulses *inward* to central ganglia are called *afferent* fibers. Those whose cells are located *within* the body and which carry impulses *outward* to muscles and glands are *efferent* fibers. Those which connect different ganglia within the body are called *intercentral* or *commisural* fibers. Those afferent fibers whose impulses excite sensations (feeling, pain, sight, etc.) are called *sensory*; those whose impulses stimulate nerve centers to send out efferent impulses to muscles are called *excito-motor*.

Of the efferent fibers those which go to muscles are called *motor*; those connected with arteries and control the flow of blood are the *vaso-motor*, and those going to glands to regulate the secretion of

liquids are *secretory* fibers. *Excitant* fibers are those which convey excitant impulses; the *inhibitory* are those which transmit impulses by that name.

References. On functions of nervous matter, C., 29; J., 233-238. On structure of nerve cells and fibers, C., 33-36; S., 255-256; J., 215-217; F. and S., 183-185. On the nervous impulse, C., 38; S., 267; J., 237; F. and S., 70. On the kinds of nerve fibers, S., 256; F., 218; F. and S., 183.

Practical Questions. 1. In what sense may nervous tissue be regarded as the "master tissue"? 2. How do nerve cells differ in structure from all the other cells of the body? 3. How does a ganglion differ from a nerve center? 4. Why is the "gray matter" supposed to be the true nerve substance? 6. Account for the grayish appearance of nerve cells and the whitish appearance of nerve fibers. 7. What purposes are served in the body by the nervous impulse? 8. With what will *one* end of a fiber always be connected? With what different things in the body may the other end connect? 9. Name examples of afferent, efferent, and intercentral nerve fibers.

CHAPTER XVII.

Divisions of the Nervous System.

There are two recognized divisions of the nervous system, known as the *Sympathetic System* and the *Cerebro-Spinal System*. Both these divisions are made up of cells and fibers and do their work through the agency of the nervous impulse. In both, the cells are collected into ganglia, and the fibers into nerves. They differ with respect to the arrangement and position of their ganglia, the distribution of their nerves, and, to some extent, in the nature of the work which they perform.

Dissection of the Nervous System. Chloroform a half grown cat (see p. 77), and fasten it to a board, as in dissection of the abdomen. Open the abdominal cavity and remove its contents, tying the alimentary canal where it is cut, and washing out any blood which may escape. Dissect for the nervous system in the following order:

1. Cut away the front of the chest, exposing the heart and lungs. Find on each side of the heart a nerve which passes by the side of the pericardium to the diaphragm. These are nerves which assist in controlling respiration, and are called the *phrenic* nerves. Find other nerves going to the different organs in the thorax.

2. Remove the heart and lungs. Find in the back part of the thoracic cavity on each side of the spinal column a number of small "knots" of nervous matter joined together by a single nerve. These are ganglia of the sympathetic system. Where the neck joins the thorax, find two sympathetic ganglia much larger than the others.

3. Cut away the skin from the upper side of the shoulder and fore leg. By separating the muscle and connective tissue where the leg joins the thorax find several nerves of considerable size. These connect with each other, forming a net work called the *brachial* plexus. From here nerves pass to the thorax and to the fore leg. Show by a drawing the main divisions of the brachial plexus.

4. From the brachial plexus trace out the nerves which pass to different parts of the fore leg. In doing this, separate the muscles with the fingers and cut only where necessary to expose the nerves. Note that some of the branches pass into muscles while others connect with the skin.

5. Remove the skin from the upper part of one of the hind legs and separate the muscles carefully until a large nerve is found. This is one of the divisions of the *sciatic* nerve. Carefully trace it to the spinal cord, cutting away the bone where necessary, and find the branches where it joins the cord. Then trace it toward the foot discovering its branches to different muscles and to the skin. Make a sketch showing the sciatic nerve and its branches.

6. Unjoint the neck and remove the head. Examine the spinal cord where exposed. Cut away the bone sufficiently to show the connection between the cord and one of the spinal nerves. On one of the roots of the nerve, find a small ganglion. Make a sketch of the cord and nerve where they join.

7. Fasten the head to a small board and remove the scalp. Saw through the skull bones in several directions. Pry off the small pieces of bone so as to show the upper part of the brain. Study its membranes, convolutions, and divisions.

8. With a pair of nippers break away the skull until the entire brain can be removed from its cavity. Examine the different divisions, and make a "side view" drawing, showing the relative position and size of the parts.

9. With a sharp knife cut sections through the different parts of the brain to show the position of the "gray" and the "white matter." Make drawings representing their arrangement in the different parts.

Make drawings of the sympathetic ganglia, brachial plexus, sciatic nerve, spinal cord, and of the brain.

The Sympathetic System.

The Cells of the Sympathetic System are collected into small ganglia which range in size, from a pin-head, to half an inch in diameter. They are situated in various parts of the body. The more important ones are to be found in *two chains* which are in front, and a little to each side, of the spinal column. Each of these chains contains 24 ganglia in addition to one found at their convergence in the lower part of the trunk. Besides these ganglia, there are several in the heart, a few in the head, and many small ones scattered throughout the body.

The Sympathetic Nerve Fibers are short and belong, for the most part, to the non-medullated variety. They form no large nerves, but the small sympathetic nerves are sufficiently numerous in some places to form complex clusters or groups. Such a group is called a *plexus*.

Of the different plexi of the body the *cardiac plexus* of the heart and the *solor plexus* of the abdomen are the most important.

Connection of Sympathetic Fibers. Fibers from the sympathetic ganglia have been traced to the non-striated muscles of the alimentary canal, to the walls of arteries, to the spinal cord, and to the other sympathetic ganglia. The heart is also well supplied with sympathetic fibers, part of which come from ganglia within it and part from ganglia situated elsewhere.

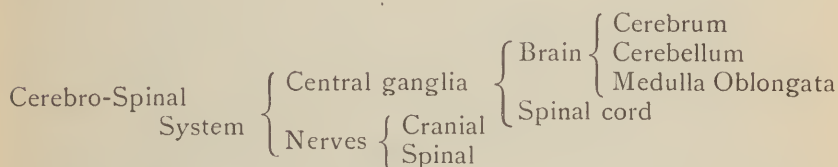
The Function of the Sympathetic System, as inferred from the distribution of its fibers, is to control the action of *involuntary* organs, especially *those concerned in the maintenance of life*. It can-

Represent by a drawing the arrangement of the ganglia and nerves of the sympathetic system.

not be stated definitely, however, that this is its *exclusive* function, as fibers from the cerebro-spinal system also go to these organs. From the close connection of the two systems, it is difficult to separate their functions. In many instances it is certain that they together control the same organ.

The Cerebro-Spinal System.

The Ganglia of the Cerebro-Spinal System form a connected mass of nervous matter, known as the brain and spinal cord, from which nerves pass to all parts of the body. The brain and cord form the center of the system, while the nerves provide the means of communication between the center and the different parts of the body. The main divisions of the system are shown by the following table:



Importance of the Cerebro-Spinal System. Most of the work of the nervous system as a whole is done by the cerebro-spinal division. It has entire control of the voluntary organs of the body and assists in the control of the involuntary organs. It contains the organ of the mind. It also provides the means for communication between the organ of the mind and the other parts of the body.

General Composition and Structure of Brain and Cord. In addition to the nerve cells which, from a functional standpoint, supply the material of chief importance in these organs, other materials are found as follows:

1. *Nerve fibers.* Some of these connect different parts of the brain and cord together, while others are continuous with the fibers which connect parts of the body with the brain and cord.

2. *Connective tissue.* This exists in small quantities and gives firmness and stability to different parts.

3. *Blood vessels and Lymphatics.* These tubes are very numerous, supplying the brain and cord with nourishment and removing waste.

The Protection of the Brain and Cord is accomplished in three different ways, as follows:

1. By the bones which surround the cavities in which they lie. What bones are these?

2. By three membranes of connective tissue which envelop them. Find a description of the position and structure of these membranes in some physiology.

3. By a layer of liquid which completely surrounds them. This occupies the large spaces in the loose arachnoidal membrane and serves as a "watery cushion" for the brain and cord.

Make a side view drawing of the brain, showing the position and relative size of the parts. Indicate on the cerebrum the places whose functions are known.

The Brain is that portion of the cerebro-spinal system which lies in the cranial cavity. From some physiology ascertain its relative size and weight, its general structure, and its divisions. Is it a double or single organ? Name its parts.

The Cerebrum forms about *seven-eighths* of the entire brain. In what portion of the cranial cavity does it lie?

• Locate the "gray matter" of the cerebrum. What portion of it is "white matter?" Of what are these "matters" composed? How is the surface for "gray matter" increased? What are the hemispheres? How are they joined?

NOTE.—If a pencil be placed over the ear and pressed down, all that portion of the brain lying above the pencil is cerebrum.

Functions of Cerebrum. The cerebrum is *the organ of the mind* and *controls voluntary motion*. These functions are performed by its

cells which are arranged into nerve centers. The centers which are concerned in mind activity are called the *psychic centers*; those controlling motion are called the *motor centers*.

Location of Cerebral Functions. It has been proven within the last few years that each part of the cerebrum, like each part of the body, has a particular work of its own. Experiments on the brains of lower animals and the study of the effect of injuries to the brain of man have both helped to prove this fact. Some of the centers which have been definitely located are the centers of *vision*, of *hearing*, of *motion*, and of *speech*.

Much difficulty, however, is encountered in locating many of the most important centers, so that the cerebrum is still, to a large extent, "an unexplored country."

The Cerebellum. Ascertain from some physiology its size, location, and general structure. Give position of its gray and white matter. Describe its convolutions and compare them with those of the cerebrum. Numerous fibers connect the cerebellum with the cerebrum, medulla oblongata, and the spinal cord.

The Function of the Cerebellum is not understood, but it would seem, from experiments upon lower animals, that it *assists the cerebrum* in *controlling voluntary* motion. Animals from which it has been removed are unable to *regulate* and *co-ordinate* their voluntary motions.

The Medulla Oblongata. Give its location, size, shape, and connections. Its gray and white matter have no definite arrangement, as in other parts of the brain, but *the gray is scattered through the white in small clusters*.

Functions of the Medulla Oblongata. The medulla is a conductor of impulses between the brain and cord and contains a number of important nerve centers. The most important of these are the centers which control breathing, and are called the *respiratory centers*.

The Spinal Cord. Ascertain its length and diameter. Does it fill the entire spinal cavity? In what does it terminate at the upper

end? In what at the lower end? Is it double or single? Give arrangement of its gray and white matter.

Functions of the Cord. The spinal cord has two distinct functions.

1. It conducts impulses between the brain and the spinal nerves.
 2. It controls a large number of the reflex actions of the body.
- Which of these functions is performed by the white matter of the cord? Which by the gray matter? Upon what do you base your conclusion?

Cerebro-Spinal Nerves. The brain and cord are connected with the different parts of the body by forty-three pairs of fiber bundles, or nerves. Those which connect with the brain are called *cranial* nerves, and those connected with the cord, *spinal* nerves.

The fibers of the cerebro-spinal nerves consist of two important classes. One class comes from the special sense-organ cells of the skin, nose, eyes, ears, and tongue. They convey impulses toward the brain and cord. What are they called? The other class makes connection with muscles and glands and conducts impulses away from the brain and cord. What are they called?

The Cranial Nerves are numbered in the order in which they leave the brain. The pair that leaves farthest toward the front is called the *first* pair, the next in order is the *second* pair, and so on. The distribution and function of these nerves are shown by the following table:

Number.	Name.	Distribution.	Function.
First Pair.....	Olfactory.....	Mucous membrane of nose...	Nerves of smell.
Second Pair.....	Optic	Retina of the eye.....	Nerves of sight.
3d, 4th, 6th Pairs	Motoros oculi.....	Muscles of the eye.....	Control motion of eyes.
Fifth Pair.....	Trigeminal.....	Skin of face, muscles of jaws, mucous membrane of mouth, and front of tongue.....	Sensory nerve of face, controls muscles of mastication, nerve of taste to front of tongue.
Seventh Pair....	Facial	Muscles of the face.....	Control muscles of expression.
Eighth Pair....	Auditory	Internal ear.....	Hearing.
Ninth Pair.....	Glossopharyngeal ..	Back of tongue, muscles of pharynx.....	Nerve of taste to back of tongue, controls muscles of pharynx,
Tenth Pair.....	Pneumogastric ..	Larynx, lungs, liver & stomach.....	Sensory and inhibitory.
Eleventh Pair...	Spinal accessory ..	Muscles of neck.....	Motion.
Twelfth Pair...	Hypoglossal	Muscles of tongue.....	Motion.

Which of the cranial nerves are purely afferent? Which contain only efferent fibers? Which contain both kinds?

The Spinal Nerves pass from the spinal cord through small openings in the spinal column. How many pairs of them? Each nerve joins the cord by two roots, the one toward the front being called the *anterior* root and the one toward the back, the *posterior* root. The posterior root contains afferent fibers while the anterior root contains efferent fibers. What will be the direction of impulses in each of the two roots? With what parts of the body are the efferent fibers probably connected? With what the afferent?

Show by a drawing a cross section of the spinal cord with roots of spinal nerves.

References. On structure of sympathetic system, S., 253; F. and S., 199; J., 226. On structure of cerebro-spinal system, S., 253; J., 219-226. On the brain, S., 257-263; F. and S., 193-199; J., 223-226. On the cord, S., 262-265; F. and S., 187-191; J., 222. Functions of the brain, S., 268-272; C., 259-263; F. and S., 199; J., 243-249. On cranial nerves, C., 260; F. and S., 196; J., 221.

Practical Questions. 1. Of what essential parts are both divisions of the nervous system composed? 2. Compare the systems with reference to arrangement of ganglia and nerves. With reference to function. 3. Why should the brain and cord be carefully protected? 4. Why are most of the fibers of the cerebro-spinal system medullated while those of the sympathetic system are non-medullated? 5. Compare the arrangement of "gray and white matter" in the cerebrum, cerebellum, medulla oblongata, and spinal cord. 6. What results would follow cutting the fifth pair of nerves where they emerge from the brain? 7. Why does an injury to the medulla oblongata cause almost instant death? 8. What result would follow the cutting of the anterior root of a spinal nerve? The posterior root?

CHAPTER XVIII.

Work of the Nervous System.

METHODS OF NERVOUS CONTROL.

The Means Employed by the nervous system in controlling the different organs of the body are the nervous impulses which are of two kinds. (Distinguish between excitant and inhibitory impulses. See p. 111.) Passing between the nerve centers, which originate the impulses, and the organs to be controlled by them, are the fibers which transmit the impulses.

Nerve centers cannot of themselves cause action. They are able to discharge their impulses *only* when they are stimulated from some source outside of themselves. Accordingly they in turn have nerve fibers coming to them from the sources of their stimuli.

The first step then in causing an organ to act is to stimulate, not the organ, but the nerve center which controls it. The center then discharges the impulses which act directly on the organ. There are two general methods of stimulating and controlling nerve centers. These are designated *voluntary action* and *reflex action*.

Voluntary Action refers to all those movements of the body which can be brought about by an effort of the will. The voluntary centers are located in the motor area of the cerebrum and are probably made to discharge their impulses by impulses which they receive from the psychic centers. The separate steps leading up to a voluntary action are about as follows:—

1. A purely mental action, such as a wish or desire. 2. Stimulation of voluntary centers. 3. Sending out of impulses from the voluntary centers to the muscles. 4. Contraction of muscles.

Reflex Action refers to those movements of the body brought about by impulses which nerve centers receive from the surface of the body. Good examples of these are the involuntary closing of the eyelids, dodging on account of some unexpected sight or noise, and the movements of one asleep, caused by some external irritation.

Experiment. Irritate the toe of a brainless frog by pinching it or pricking it with a pin. (See Appendix.) Observe and account for the frog's movements. Rub a piece of rock salt against the skin of the abdomen and observe the result. What is the positive evidence that the frog's movements are not voluntary?

State results
and give infer-
ences.

Most of the reflex centers are located in the medulla oblongata, spinal cord, and the ganglia of the sympathetic system. The impulses which stimulate them come from *sense organs*. Since the action is in the direction from which the exciting impulses come it is called *reflex*, which means *bending back*.

The different steps in the production of a reflex action are as follows:

1. Strong stimulation of sense-organ cells on the outside of the body. 2. Excitation of reflex centers by the impulses from the sense-organ cells. 3. Sending out of impulses from the reflex centers to the muscles. 4. Contraction of muscles.

Draw a diagram to illustrate reflex action.

Study the movements of your own body for the purpose of detecting reflex actions. Determine the purpose of the different reflex movements which you discover.

Habit. Any nervous action becomes easier by repetition. If the same act be repeated over and over a great many times, the cen-

ters which control it, may become independent of their controlling sources. They are then described as *automatic*, or self-acting. The formation of habit is illustrated in learning to walk, and in acquiring all kinds of skill. Actions which at first required constant effort of the will, are in time performed with such ease that the will need direct them only in a general way.

Habit is necessary for economy in nervous energy, the greatest saving being on the part of the mind.

Control of Important Processes.

The Control of the Blood Supply to the different organs of the body is effected through the management of the heart's contractions and the muscular tissue in the walls of the arteries.

Control of the Heart. The heart has a small nervous system of its own, composed of sympathetic ganglia which act automatically. Impulses from these are able to keep up its continued contractions, but are unable either to increase or diminish its motion. The heart is connected with other parts of the nervous system by three kinds of nerve fibers.

1. A set of *sensory* fibers which connect with the medulla oblongata and report

Draw a diagram illustrating control of the heart.

the condition of the heart to the nerve centers located there.

2. A set of *inhibitory* fibers which also connect with the medulla oblongata, but these carry impulses to the heart to *slow* its motion.

3. A set of *excitant* fibers which connect with the sympathetic system and bring impulses to the heart to *quicken* its motion.

Impulses from the medulla oblongata and the sympathetic system are thus able to *regulate* the heart's action. If there should be a greater demand than usual for blood over the body, how will the heart be made to beat faster? After the extra demand has ceased, how will the heart be made to beat more slowly.

Control of blood supply to different organs Organs when active receive more blood than when inactive. The quantity of blood flowing into an organ is determined by the size of the arterial tubes which penetrate it and this is subject to variation.

If the walls of the arteries be examined they are found to contain *bands of muscular tissue*. These bands are thickest where the arteries enter organs and are naturally in a *moderate state of contraction*. Should an organ need more than the usual amount of blood, *inhibitory* impulses go to the muscular walls of its arteries, causing them to relax. How will this increase the amount of blood which enters the organ? If it be desirable to decrease the blood supply to a certain organ, *excitant* impulses cause the muscular walls to contract. How will this diminish the amount of blood going to that organ?

Control of Respiration. Afferent fibers extend from all parts of the mucous membrane, lining the air passages, to the medulla oblongata. These report the condition of the air passages to that part of the medulla known as the *respiratory* centers. From these centers one set of *excitant* fibers go to the diaphragm, another to the intercostal muscles, and another set to the abdominal muscles. Impulses from these fibers produce the requisite contraction of muscles to cause the alternate expansion and contraction of the thorax.

The usual method of stimulating the respiratory centers is *by the blood* which passes through them. If the blood contain a *small amount of oxygen* it causes the centers to send out impulses to *increase* the respiratory acts. If it contain a *large amount of oxygen*, the impulses are *less* in strength. This explains how physical exercise may increase the force and rapidity of the respiratory acts. The muscles, at work, consume large quantities of oxygen and give carbon dioxid

to the blood. In this way they get the blood into such a condition that it can act strongly upon the respiratory centers.

The respiratory centers may also be stimulated in other ways. Should a foreign substance get into the larynx, violent coughing results. This is caused by nerve cells in the mucous membrane, discharging impulses to the respiratory centers, which stimulate them to send out impulses to the respiratory muscles. In like manner an irritation of the mucous membrane of the nostrils causes sneezing. It is thus seen that the respiratory centers may be made to act *reflexively* by impulses from sense-organ cells.

Voluntary centers in the brain are also able to stimulate the respiratory centers and make them act under the direction of the will. *Make a drawing to illustrate the control of salivary glands.* Furnish illustrations of this fact.

Control of Digestive Processes. Afferent fibers leave the mucous membrane at all points along the alimentary canal and connect with nerve centers situated in the brain, spinal cord, and sympathetic ganglia. These make known the condition of the canal at the different centers. From these centers, fibers go *to the glands* which supply the digestive fluids, *to the muscles* which are concerned in digestion, and *to the walls of the arteries* which supply the blood to the various digestive organs.

The food pressing against the mucous membrane, causes a discharge of impulses to the different nerve centers and these, in turn, stimulate the organs with which they are connected. By this arrangement, the food itself causes that work to be done which is necessary for its digestion. Thus it is seen that the method of controlling the organs of digestion is through reflex action.

Sensations.

What is a Sensation? We have already noticed the existence of a large class of nerve fibers which are connected with nerve cells at the outside of the body and which conduct impulses inward to nerve centers. (What are these fibers called? What effect do their impulses have upon reflex centers?) Impulses passing along these fibers are able, when they reach the brain, to stimulate certain of the psychic centers. This causes a peculiar form of nervous action, called a sensation, the nature of which is not understood. For our purposes we may regard the sensation as *an activity of psychic centers caused by afferent impulses*.

The Purpose of Sensations is to give the mind information. Intelligent action makes it necessary for the mind to know the condition of the body itself and also the physical conditions which surround it. Through the interpretation which the mind gives to these effects of afferent impulses it is made aware of these conditions. Sensations are of two kinds—*general* and *special*.

General Sensations are caused by impulses coming from different parts of the body, but which, so far as known, do not originate in nerve terminations designed for that purpose. They seem rather to result from a general condition of the nervous system. Good examples of general sensations are *hunger, thirst, nausea, pain*, and the feelings of *comfort* and *discomfort*.

Through the general sensations the mind becomes aware of the condition of the different organs and can modify the activities of the body to suit their condition. Show the value of hunger and thirst, of comfort and discomfort in the protection of the body.

Special Sensations are caused by impulses which come from definite places at the surface of the body, called the *special sense organs*. There are at least six different kinds of special sense organs, the sensations which they cause being known as the *special senses*. These are sight, hearing, smell, taste, touch, and temperature.

A Special Sense Apparatus includes all the parts necessary for the production of a special sensation. These parts are as follows:

1. Sense-organ cells to originate the impulses. 2. Nerve fibers to transmit the impulses. 3. Nerve centers which receive the impulses and give rise to the sensation.

Through the special sensations the mind becomes acquainted with the condition of the surroundings of the body. To what extent do the senses of sight, hearing, and touch make one acquainted with his surroundings?

Special Sense Stimuli. Each sense organ is capable of being stimulated by a single form of energy. This is known as the *stimulus* for that sense organ. For example, the sense organ cells of sight are made to discharge their impulses by the action of light. Light then, is their stimulus. Furnish other illustrations.

Touch is the simplest of the special senses. Its sense-organ cells are located in the touch corpuscles of the skin. Their stimulus is *pressure*. When pressure is applied to the skin impulses are started, which, when transmitted to the brain, cause an activity of the psychic centers, called the touch sensation. At what places on the body is the sense of touch best developed?

Experiment. Place the points of a pair of dividers on the back of the hand of one who has been instructed to look in the opposite direction. Is one point felt or two? Repeat several times, changing the distance between the points until it is fully determined how near together they must be to be felt as one. In like manner test other parts of the body, as tips of fingers and back of neck. From a comparison of results, determine what portion of the body is most sensitive.

Give results
and inferences.

The Temperature Sense. It was at one time supposed that the touch corpuscles were also stimulated by heat and cold, but it is now known that there are special sense-organ cells for temperature. When the temperature of objects near the skin is the same as the skin, no sensations are produced. But when their temperature is above or below that of the skin, the temperature cells are made to discharge impulses.

Recent investigation proves the sense-organ cells of temperature to be of two kinds—one kind stimulated by heat, the other by cold.

“If a metal point, lightly weighted, be slowly and evenly moved over the skin, it gives rise to sensations of touch at some places and sensations of temperature at others. If it be a little warmer than the skin, at certain places it causes a sensation of heat. If it be colder than the skin, it gives rise to a sensation of cold as it travels over some places. The ‘cold sensation’ spots are different from the ‘warm sensation’ spots and are constant in the same individual from day to day.”
—Martin’s Human Body.

The Sense of Taste. The sense-organ cells of taste are scattered over the upper surface of the tongue and perhaps the lower portion of the soft palate. They are found in little bulb-shaped organs called the *taste buds*. The inner ends of these cells connect with fibers which join the nerves of taste. The stimulus for the sense-organ cells of taste are substances in the *liquid* state. Solid substances, to be tasted, must first be dissolved.

Little is known of the manner by which the different tastes are produced. The different kinds recognized are sweet, sour, bitter, salty, and alkaline. Flavors, such as vanilla and lemon, and the flavors of meats and fruits are really smelled, not tasted. Of what use is the sense of taste?

The Sense of Smell. The sense-organ cells of smell are located in the mucous membrane of the nasal passages. These cells are stimulated to discharge their impulses by the passage of odors through the nostrils. The mucous membrane of the nose also contains ciliated cells and touch corpuscles. The latter make it sensitive to the contact of foreign bodies. The olfactory, or smelling cells, are wedged in between the ciliated cells, with one end touching the surface of the membrane and the other end connected with fibers which transmit the impulses to the brain.

Show by a drawing the branching of the olfactory nerve.

In order to smell, the odor *must be in motion* through the nostrils, and must come in direct contact with the olfactory cells. Of what use is the sense of smell? Describe the nerves of smell.

Sight and Hearing. The importance of these senses, the complexity of their sense organs, and the nature of their stimuli make necessary their study in separate chapters.

References. On reflex action, S., 272-273; J., 240-250; F. and S., 191; C., 36-39, 268-269. On habit, C., 281; S., 275. On control of circulation, J., 113. On control of respiration, J., 169; C., 122. On control of digestion, J., 153. On the sense of touch, S., 323-325; F. and S., 202; J., 255; C., 286. On the sense of taste, S., 308-310; F. and S., 203-204; J., 259; C., 296. On the sense of smell, S., 312-314; F. and S., 206; J., 257; C., 298. On the sense of temperature, S., 226-230, 325; J., 257; F. and S., 203; C., 285, 290.

Practical Questions. 1. How does voluntary action differ from reflex action? 2. Are weak or strong impulses required to cause voluntary muscles to act reflexively? 3. State the purpose of reflex action. 4. Trace the impulses which cause the hand to be jerked away from a hot stove before the owner feels pain. 5. How does habit save nervous energy? 6. Why are habits hard to change? Show the importance of forming useful habits. 7. Is there a relation between "character building" and "habit forming"? 8. Account for the fact that violent exercise makes the face first pale and then red. 9. During hard study where is the excess of blood needed? How is it obtained? 10. How does running cause one to breathe faster? 11. To what class of nervous actions do those of digestion belong? 12. How does the presence of food in the mouth cause a flow of the saliva? 13. Compare special and general sensations with reference to their cause and the purposes which they serve. 14. Of what value is pain in the protection of the body? 15. What different things must happen in order to produce the sensation of touch? 16. What different kinds of sense organs are found in the skin? 17. How is the mind made aware of the presence of solids, liquids, and gases?

CHAPTER XIX.

Sound and the Sense of Hearing.

Sound is a form of vibration which is capable of stimulating the organ of hearing. It originates in vibrating bodies.

Experiments. 1. Strike a bell an easy blow and hold against its side some light substance, as a pith ball attached to a thread. Account for the movements of the light substance.

2. Sound a tuning fork by plucking, or striking it against the table. Its vibrations can be felt. If it is a large fork they can be seen. Place the vibrating prongs in water. Observe and account for the result.

Give results
and inferences.

All sound producing bodies are known to be in a state of vibration at the time of giving out sound. Account for the production of sound by the violin, organ, piano, flute, and jews-harp. All vibrations, however, are not classed as sound, but only those that are more rapid than 16 per second and less rapid than 40,000 per second. Vibrations whose rate is less than 16, or more than 40,000 per second, are not able to cause the sensation of hearing.

How Sounds Differ. Sounds differ in *pitch*, *intensity*, and *quality*. By pitch is meant the height of a sound. It depends upon the *rapidity of the vibrations*. By intensity is meant the energy of the vibrations—their ability to act on bodies and to set them in motion.

It is nearly expressed by the word loudness. Intensity depends upon the *amplitude*, or *width*, of the vibrations. Quality is that peculiarity of sound which enables us to distinguish one sound from another having the same pitch and intensity.

Experiments. 1. Draw the edge of a visiting card over the teeth of a comb. The sound produced from each separate tooth may be considered a vibration. Account for the fact that a slow motion produces a tone of low pitch and a rapid one, a tone of high pitch.

2. With a violin or guitar, show how pitch is affected by the length, tension, and size of the strings.

3. Show by plucking a string of a guitar, first lightly and then forcibly, that the loudness of the sound depends upon the amplitude of its vibrations.

Transmission of Sound Vibrations. Sound vibrations may be transmitted, or carried, from where they originate to other places by *all* elastic substances. *The atmosphere*, however, since it presses in close against vibrating bodies and is in sufficient abundance to form a connecting medium between all things on the earth, *is the most important transmitter of sound*. (See p. 36.) Vibrating bodies set the air in contact with them into vibration. These vibrations pass through the air in the form of waves, called *sound waves*. When sound waves strike against *delicately poised* substances they set them into vibration.

Experiment. Wave a flat, stiff body, such as a chart or board, back and forth through the air, in front of, and about ten feet away from, a large sheet of paper, which is held loosely by its upper corners. The moving object imparts its motion to the air and the air transmits it to the paper, causing it to vibrate. Apply the principles involved in this experiment to the origin, transmission and effect of sound waves.

Nature of Sound Waves. Sound waves are not, like the waves on water, made up of crests and troughs, but are composed of *condensed* and *rarefied* portions. The condensed portion is formed when a given surface of the vibrating body moves *toward the air* and the rarefied portion when it *recedes*. The length of a sound wave is the distance across one condensed portion and one rarefied portion. Sound waves vary in length from a few inches to several feet.

Importance of Sound Waves. Sound waves sustain a very important relation to the subject of physiology. By means of them,

man, in common with most animals, becomes acquainted with a certain condition of surrounding objects and is able to communicate with his fellows. Accordingly, the body is supplied with *a contrivance for producing sound vibrations* and also *a contrivance*, by means of which, *the vibrations are able to stimulate a part of the brain and produce the sensation of hearing*. Name and locate these contrivances.

Production of Sound in the Body.

The Sound Producing Mechanism of the body consists essentially of three parts:

1. Delicately arranged bodies easily set into vibrations.
2. Contrivances for acting on the vibrating parts so as to produce changes in pitch, quality, and intensity.
3. An arrangement for supplying the necessary force to cause vibrations.

The first part of this mechanism consists of the vocal cords; the second part comprises the muscles of the larynx and throat; while the situation of the vocal cords in the air passages enables the muscles of respiration, acting on the respired air, to supply the necessary force for producing the vibrations.

The Larynx (see p. 40) consists of a short tube, the walls of which are made up of nine separate pieces of cartilage, joined together by short ligaments.

Mucous membrane lines the inside of the larynx, while small muscles cover a considerable portion of the exterior surface. The vocal cords consist of two folds in the mucous membrane on opposite sides of the larynx, covering strips of "elastic tissue" which connect with pieces of *movable* cartilage. By the action of muscles upon the cartilage the tension of the cords may be changed and differences in pitch produced. Above the vocal cords in the larynx, and resembling them in appearance, are two other folds in the mucous membrane. These are called the false vocal cords.

The Voice is Produced by the respired air setting the vocal cords into vibration. When the cords are not in use they are in a relaxed condition, so that the air moving through the larynx does not

strike against them. A contraction of the muscles connected with the movable cartilage pulls them out so that they partly close the passage.

The effect of the vocal cords is greatly increased by reason of their situation in the air passages, which together act on the principle of an organ pipe. Through the action of the tongue, lips, soft palate, and respiratory muscles the sound from the cords is much modified and separated into distinct tones of short duration, forming the elements of articulate speech.

Observations. 1. Lightly grasp the larynx with the fingers while talking. Observe the changes both in the position and shape of the larynx in the production of different sounds.

2. Observe the differences in the action of the muscles of respiration in the production of loud and faint sounds.

3. Pronounce slowly the vowels, A, E, I, and O, and the consonants C, F, K, R, S, T, and V, noting the changes in the shape of the mouth, the position of the tongue, and the action of the lips.

Detection of Sound in the Body.

The Structure of the Organ of Hearing adapts it perfectly to the nature and properties of sound waves. It consists of a contrivance for enabling sound waves to stimulate the sense-organ cells of hearing and cause them to send impulses to the brain. The organ of hearing consists of three parts: the *external* ear, the *middle* ear, and the *internal* ear.



Complete the sketch, showing and naming the divisions of the ear.

The External Ear consists of the part on the outside of the head, called the pinna, or auricle, and the tube leading into the internal ear, called the *auditory canal*. This canal is closed, at its inner end, by a thin membrane called the *membrana tympani*.

The pinna, by its peculiar shape, is able to *reflect* sound waves into the auditory canal which, in turn, conducts them to the

Membrana Tympani. This membrane consists of three thin layers. The outer layer is a continuation of the membrane lining the auditory canal; the inner, is a part of the membrane of the internal ear; while the middle is a layer of connective tissue. Being thin and delicately poised, the membrana tympani is easily made to vibrate by the sound waves which enter the auditory canal.

The Middle Ear, or Tympanum, is an irregular cavity in the temporal bone. It is lined with mucous membrane and is connected with the pharynx by a canal, known as the *eustachian tube*. Extending across the middle ear and connecting the membrana tympani, on one side, with a membrane closing a small passage to the internal ear, on the other side, is a chain of three small bones. (Find names of these bones.)

The eustachian tube admits air into the middle ear and, in this way, maintains an equality of atmospheric pressure on the two sides of the membrana tympani.

Experiment. Close the nose and mouth tightly with the hand and attempt to exhale air from the lungs. Account for the pressure in the ears. Repeat the experiment, attempting to inhale instead of exhale.

State
results.

The purpose of the chain of bones is to transmit vibrations from the membrana tympani to the

Internal Ear, or Labyrinth. This division of the ear consists of a group of membranous tubes which lie in corresponding channels in the temporal bone. There are three parts to the labyrinth: The *semicircular canals*, the *cochlea*, and the *vestibule*. The different parts are connected and the cochlea and semi-circular canals may be considered as branches of the vestibule.

Of the different parts of the labyrinth, the cochlea is perhaps the most important, as it contains the auditory cells. It is a spiral tube, coiled like a snail shell, with three internal divisions running its entire length. One division connects with the vestibule and is called the *scala vestibula*. Another reaches to the tympanum and is called the *scala tympani*. The other lies between these two and is called the *scala media*, or cochlear canal. This is the true organ of hearing and contains the

Represent a section of the cochlea, naming parts.

Auditory Cells. These are spread out over a thin membrane, called the *basilar* membrane. Fibers from the auditory nerve connect with the cells and transmit their impulses to the brain. Sound vibrations are communicated to them by the liquid which fills all three of the divisions of the cochlea.

How we Hear. Sound waves which originate at vibrating bodies are transmitted by the air to the external ear. The pinna and auditory canal direct the vibration against the membrana tympani and this is made to vibrate. The vibration of this membrane causes the chain of bones to vibrate and it, in turn, communicates the vibration to the liquid in the labyrinth. This liquid vibrating against the two sides of the *scala media*, sets the auditory cells into vibration, causing them to discharge nervous impulses. These impulses, *on reaching the brain*, cause the *sensation* of hearing.

Many things connected with hearing are not fully understood. The smallness of the true organ of hearing and its position in the temporal bone make its study exceedingly difficult.

The Function of the Semi-circular Canals has not, as yet, been demonstrated. On account of the directions in which they extend through the temporal bone and the effect which their removal has upon lower animals, they are supposed to assist in keeping the body balanced.

Care of the Ear. The ear being a delicate organ, injury to it often results from careless or rough treatment. The ear wax should not be "picked" out of the auditory canal. The ear has a way of its own for discharging it; besides the practice is attended with considerable danger. Children's ears should never be pulled or boxed. In removing foreign substances which may have accidentally gotten into the ear, use only *gentle* means. In case of serious trouble there should be no delay in consulting a physician.

References. On structure of larynx, J., 162, 186, 192; F. and S., 235; S., 125; C., 55, 321. On dissection of larynx, F. and S., 235-237; C., 321. On production of voice, C., 320-327; F. and S., 238. On speech, C., 326-327; F. and S., 239. On nature of sound, C., 317; F. and S., 233. On structure of the ear, C., 316-318; J., 280-283; S., 316-320; F. and S., 226-228. On care of the ears, S., 321, 354; C., 318. How we hear, F. and S., 234.

Practical Questions. 1. What is a sound wave? How does it originate? How is it transmitted? State its effects on delicately poised bodies. 2. How do sound waves differ from waves on the surface of water? 3. What are the advantages of having the body supplied with a sound receiver and a sound producer? 4. Describe the plan for the production of sound in the body. 5. Account for the production of pitch and intensity by the organ of the voice. 6. How is the sound produced by the vocal cords changed into speech? 7. What parts of the organ of hearing are concerned in transmitting sound waves? 8. Give purpose of the middle ear. 9. Trace a sound vibration from a bell to the auditory cells, and the impulse it causes from the auditory cells to the brain. 10. Why should not the ears be picked?

CHAPTER XX.

Light and the Sensation of Sight.

Light is supposed to be a form of wave-like motion thrown off from bodies highly heated. Such bodies are said to be luminous. Name examples. Light waves pass from luminous bodies, in straight lines in all directions. When they strike other bodies, they may be *reflected, absorbed, or transmitted*. Name a body which reflects light; one which absorbs light; one which transmits light. A single line of light is called a light *ray*. A collection of rays is called a *beam* of light.

Kinds of Reflection. Rays of light striking against the smooth surface of a mirror are thrown off in definite directions, depending on the angle at which they strike the mirror. (Illustrate by holding a mirror in the direct rays of the sun.) This is called *regular reflection*.

Rays of light which strike rough surfaces are reflected in all directions, apparently without reference to the angle at which they strike. (Illustrate by placing a piece of white paper in the direct rays of the sun. It matters not from what direction it is looked at, intense rays of light from it strike the eye.) This kind of reflection is called *diffusion*.

Refraction of Light. When light passes from one medium into another of different density, as for instance, from air into water, it is bent out of its course. This bending is called *refraction*. If different light rays are bent so that they meet at a point, they are said to be

focused, and the point of meeting is called the *focus*. If rays which are reflected from a given point on a body are focused, they form a picture or *image of that point*. *A collection of the images of all the reflected points of a body forms an image of the whole body.*

Experiments. 1. Heat an iron, or platinum wire in a clear gas flame. Observe that as it is heated to a high temperature it gives out light rays, or becomes luminous.

2. Cover one hand with a white handkerchief and the other with a piece of black cloth and hold both, for a short time, in the direct rays of the sun. Note and account for the difference in temperature which is felt.

3. Stand a book, or block of wood, by the side of an empty pan in the sunlight, so that the end of the shadow falls on the bottom of the pan. Mark the place where the shadow terminates and fill the pan with water. Account for the shadow's changing in length.

4. Place a coin in the center of an empty pan and have the members of the class stand where the coin is barely out of sight over the edge of the pan. Fill the pan with water and account for the coin's coming into view.

5. Hold a piece of card-board, about eight inches square and having a smooth, round hole in it an eighth of an inch in diameter, in front of a lighted candle in a darkened room. Back of the opening place a muslin, or paper screen. An image of the candle will be formed on the screen. Account for the fact that it is inverted.

6. Hold a convex spectacle lens between the card-board and screen so that the rays of light pass through it. The image should become smaller and more distinct.

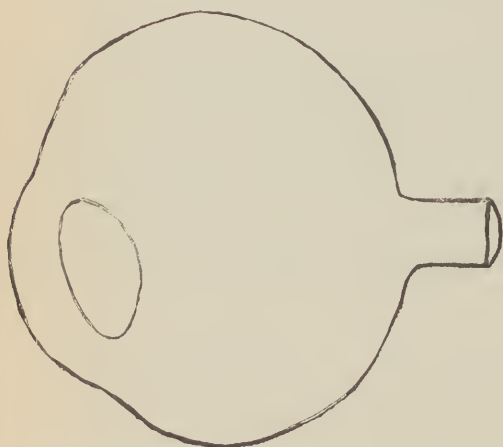
Construct a drawing to show the formation of the image through the opening in the screen.

How we See. There is no producer of light in the body. In seeing we make use of the rays of light reflected from the surfaces of bodies by the process of diffusion. To see an object four things must happen: 1. Light rays must pass from the object to the eye. 2. These rays after being focused, must stimulate the sense-organ cells to discharge their impulses. 3. The impulses must be transmitted to nerve centers in the brain. 4. The centers, in response to the impulses, must become active. This activity is the sensation of sight.

The Organ of Sight is adapted by its structure to the nature and properties of light waves. It consists of the eyeball, or globe of the eye, together with the tissues for its protection and control.

On dissection of the eyeball see C., 302-305.

The Globe of the Eye is a contrivance for focusing the rays of light from an object, upon the sense-organ cells of sight. Its parts are as follows:



Complete the drawing, naming the parts.

1. The *cornea*, a clear transparent membrane, is in the center of the front of the eye. It fits into the *sclerotic coat* which surrounds it on all sides, as the crystal of a watch into its case. It admits light into the globe.

The *sclerotic coat* is white, dense, and firm. It surrounds the remaining portion of the eyeball, except where the optic nerve enters. At this place it continues back as the sheath of the nerve. The portion of it seen in front, is called the "white of the eye."

2. The *sclerotic coat* is lined by a dark colored coat, the *choroid*, which is crowded with the blood vessels that furnish most of the nourishment to the eye. On account of its color it is able to absorb surplus rays of light. The *choroid* coat is continued forward into the circular curtain back of the cornea called the *iris*. The *iris* is the colored portion of the eye. In the center of the *iris* is a circular opening called the *pupil*.

3. Lying next to the choroid coat, in the back portion of the eyeball and covering about two-thirds of its inner surface, is the *retina*. Though only about one-fiftieth of an inch in thickness, it is very complex in structure and contains the *sense-organ cells of sight*. These cells, on account of their peculiar shapes, are called the *rods* and *cones*. Fibers from the optic nerve connect with these cells and conduct their impulses to the brain. That portion of the retina immediately back of the pupil, called the *yellow spot*, is the place where it is most sensitive. At the place where the optic nerve enters the eye, the rods and cones are absent. This is called the *blind spot*.

4. The *crystalline lens* is situated immediately back of the iris. It is a transparent solid body, convex on both sides, being about one-third of an inch in diameter and one-fourth of an inch thick. It is quite elastic. It is surrounded and held in position by a membranous capsule, the edges of which connect with an extension of the supporting connective tissue of the retina, called the *suspensory ligament*.

Surrounding the lens, and lying at the junction of the iris and choroid coat, is a circular band of muscle, called the *ciliary muscle*. Its contraction has the effect of diminishing the long diameter and increasing the thickness of the lens.

The lens, together with its surrounding membranes and the ciliary muscle, form a partition across the front of the eyeball. The small space in front of this partition is called the *anterior chamber*; that back of it is the *posterior chamber*.

5. Two liquids—the *aqueous* and *vitreous* humors—occupy the two chambers of the eyeball. The aqueous humor is a thin, watery liquid and occupies the anterior chamber. The vitreous humor is dense and jelly-like, and occupies the posterior chamber. Both liquids help to hold the eyeball in shape and assist in focusing light rays.

Regulation of the Quantity of Light Entering the Eyeball.

The quantity of light entering the posterior chamber of the eye is

regulated by the size of the pupil. The iris contains two sets of involuntary muscles. One set encircles the pupil while the other is attached between the inner and outer margins of the iris. (See work of sphincter and radiating muscles, p. 101.) By the action of these muscles the size of the pupil is modified to suit the quantity of light needed. What effect does a contraction of the circular muscles have on the size of the pupil? What, the contraction of the radiating muscles?

Make drawing to show the arrangement of the muscles of the iris.

To Prove the Presence of the Blind Spot. Close the left eye and with the right gaze steadily at the spot on the left side of this page. Starting with the book a foot or more from the face, move it slowly



toward the eye. One place will be found where the spot on the right entirely disappears. On bringing it nearer, however, it is seen again. As the book moves forward or backward, the position of the image of this spot on the retina changes. Where is it when the spot cannot be seen?

Structure and Action of the Eyeball Illustrated. In the center of one end of a chalk box, having a tight fitting lid, cut a round hole half an inch in diameter. Over this hole fasten a small piece of tin which has in its center a smooth, round hole three-sixteenths of an inch in diameter. Back of the hole fasten by a suitable support a convex lens, such as may be obtained from an old pair of spectacles. At the upper left hand corner of the same end of the box, cut another opening, making it one-fourth of an inch in diameter. Fit a stiff piece of white paper in the back end of the box and arrange it so that its position may be shifted.

If the lid be placed on the box and the opening in the center turned toward a window, by looking in the hole at the corner of the box, an inverted image will be seen on the paper screen. Care must be taken that the head does not obstruct the rays of light which pass from the window to the hole. The distinctness of the image will be increased by a coat of black paint on the inside of the box. Compare the box to the eyeball, part for part.

Focusing Power of the Eyeball. It is necessary for distinct vision that the light from the surfaces of objects be focused upon the retina. This means that the rays of light passing from each of the

different points on the object, shall meet at corresponding points on the retina. This collection of the images of the surface points of the object upon the retina, forms the image of the object as a whole.

The instruments used in Physics for focusing light rays are called lenses. The eye is provided with two of these. The cornea with the liquid behind it, forms one of them; the crystalline lens is the other.

Show by a drawing the focusing of light rays by the eyeball.

Accommodation. Rays of light from near objects enter the eyeball at a different angle from those of distant objects. Rays from distant objects are nearly parallel while those from near objects are *divergent*—the divergence increasing as the object comes nearer the eye. To focus rays of light coming from objects at different distances requires a change in the curvature of the crystalline lens. To overcome the effect of increased divergence on the part of light rays, the convexity of the lens is increased; to focus rays of light more nearly parallel, the lens becomes flatter and thinner. This changing of the lens to suit the distance of the object viewed, is called *accommodation*.

The Method of Accommodation is difficult to determine. The accepted explanation is as follows:

The lens is suspended back of the pupil by its membranous capsule and the suspensory ligament. The suspensory ligament is attached to the sides of the eyeball in such a manner that it exerts continuous tension on the membranous capsule which, in its turn, exerts pressure on the sides of the lens, tending to flatten it.

This arrangement brings the elastic force of the eyeball into opposition with the elastic force of the lens. The ciliary muscle plays between them in the following manner:

1. *To thicken the lens*, the ciliary muscle contracts, pulling forward the suspensory ligament and releasing its tension on the membranous capsule. This permits the lens to thicken by virtue of its own elastic force.

3. *To flatten the lens* the ciliary muscle relaxes, the elastic force of the eyeball resumes the tension on the suspensory ligament and the membranous capsule resumes its pressure against the sides of the lens.

Experiment. Hold a pencil between the eyes and a window, looking at the window. Why does the pencil appear blurred and indistinct? Keeping the

pencil in the same position look at it, instead of the window. Account for the appearance of the window. Look from one to the other several times in succession. Is it easier to look from the distant to the near object, or vice versa? Why?

Results.

Inference.

Defects in Focusing Power. An eye in a natural, or normal, condition is able, when at rest, to focus objects which are 20 feet or more away and is able to *accommodate* itself to objects as near as five inches.

An eye is said to be *myopic* or *short-sighted* when it is unable to focus light rays from *distant* objects. In such an eye, the ball is too long for the convexity of the lens, and the image falls in front of the retina.

A *longsighted* or *hypermetropic* eye is one which can focus the rays from distant objects but not those from near objects. In such an eye the ball is too short for the convexity of the lens and the image of the object, if formed, would fall behind the retina. These defects in focusing are remedied by wearing spectacles whose lenses are shaped so as to correct the defect in the eye. Shortsightedness is corrected by a *concave* lens and longsightedness by a *convex* lens.

In *astigmatism* all parts of the eye fail to focus at the same distance. As a result one part of an object is seen distinctly while another part is dim. This defect is generally due to some fault in the curvature of the cornea. It is reme-

Make drawing to show the muscles which move the eyeball.

died by lenses ground to correct the particular defects which happen to be present in a given eye.

The Movements of the Eyeball are brought about by the action of six small muscles attached to its outside. Four of these, the *recti* muscles, are attached between the upper, lower, inner, and outer sides of the ball, and the back portion of the socket. These are able to turn the eye upward, downward, inward, and outward. The other two, the *oblique* muscles, are attached between the upper and lower portions of the ball and the sides of the socket. These rotate the eye.

Protection of the Eyeball. The delicacy of the organ of vision, as well as its importance, requires that it be carefully protected. The different things which aid in its protection are as follows:

1. Its position within an open cavity in the skull bones.
2. The cushions of fat which line this cavity.
3. The lids which provide a *movable* covering.
4. The *conjunctiva*, a thin, sensitive membrane which covers the front of the eyeball and lines the underside of the lids. This membrane prevents foreign bodies from getting behind the eyeball.
5. The tears. (Consult some text book with reference to the supply of tears to the exposed surface of the eyeball.)
6. The eyebrows and eyelashes.
7. The general oversight of the nervous system.

Care of the Eyes. On account of their delicacy, the eyes are easily injured by careless use. If the following precautions are observed, many of the common ailments of the eyes may be prevented:

1. Never read where the light is very intense or very dim.
2. When the eyes hurt quit using them.
3. Never hold a book so that the smooth page reflects light into the eyes. The best way is to sit or stand so that

Make a drawing to show the tear system.

light passes from over the shoulder to the book. 4. Never study by a lamp which is not shaded. 5. When the eyes are weak, wash them frequently in water containing enough salt to slightly smart them. When something serious affects the eyes, consult a physician.

References. On structure of the eyeball, J., 263-265; F. and S., 210-214. On muscles of the eye, J., 274; F. and S. 208; C., 301. On dissection of the eyeball, C., 302. On accommodation, J., 266; F. and S., 216-219; C., 308, 309. On how we see, J., 266; F. and S., 214. Care of the eyes, S., 303; C., 312-314. On defects in focusing, J., 273; F. and S., 219; S., 302.

Practical Questions. 1. When are light rays reflected? When absorbed? When transmitted? When refracted? 2. Where does the light come from which enables us to see objects? 3. How may the light rays reflected from an object be made to form an image of that object? 4. What different things must happen in order that we may see an object? 5. What portions of the eyeball transmit light? What absorb light? What reflect? What refract light? 6. Show how the iris, the crystalline lens, the retina, the ciliary muscle, and the cornea aid in seeing. 7. Trace a ray of light from a visible object, through the different media, to the retina. 8. What change in the shape of the crystalline lens occurs when we look from a distant to a near object? Why is this change necessary? How is it brought about? 9. Show how concave lenses remedy short-sightedness. How convex lenses remedy longsightedness. 10. Of what importance are the muscles attached to the eyeball? 11. Describe the conjunctiva and give its function. Why should it be sensitive?

CHAPTER XXI.

Hygiene of Nervous System.

Delicacy of Nervous Tissue. No tissue of the entire body is so easily injured as the nervous tissue. Its peculiar use in the body necessitates an extreme delicacy of structure. For this reason the ganglia and nerves occupy those places in the body which afford greatest protection from external injuries. There is no provision, however, for the protection of the nervous system from the results of continued misuse on the part of the individual.

Since nervous tissue provides for the control and regulation of all the organs of the body, its weakness is as frequently manifested through the inefficiency of different organs as through well recognized symptoms of nervous derangement. Poor digestion, irregularities of the heart's action, troubles with the eyes, etc., are frequently indications of an overtaxed nervous system, and disappear when this system regains its normal condition.

Mental Work is conducive to the health of the nervous system. Even severe mental exertion may be undergone without bad effects, provided proper hygienic conditions are observed. But "brain workers" as a class are more or less liable to nervous derangements. For this reason they should observe at least the more general rules in caring for the nervous system and practice economy in the use of nervous energy.

Plenty of Sleep is one of the first requirements of the nervous system. This is the time during which the exhausted brain tissues

are being replenished. To shorten the natural period of sleep is to weaken the brain and lessen its working force. No one should attempt to get along with less than eight hours of sleep each day and most people require more.

Physical Exercise is another requirement of healthy nervous action. It is important in a general way because of its beneficial effect upon digestion, circulation and excretion, thereby insuring a liberal supply of oxygen and food material to all the tissues. (See p. 102.)

It also has a direct effect upon the nervous system. Mental work causes an excess of blood to be sent to the brain and a diminished amount to other parts of the body. Physical exercise will redistribute the blood and equalize the circulation. Light exercise, therefore, should follow hard study. The student on retiring at night is greatly assisted in getting to sleep, and put in better condition for the next day's work, by 15 or 20 minutes of light gymnastics.

Fretting and Worrying are unhealthful forms of nervous activity which should be carefully avoided. Certainly the vast quantity of nervous energy which may be expended in these ways cannot be used in doing mental work. A fretting person may be likened to the leaking boiler of a steam engine. The escaping steam not only lessens the working power of the engine but is disagreeable and distracting as well. "It is worry not work that causes the mental wreck."

Cheerfulness. Mental states have much to do with the healthfulness of the nervous system. Angry and resentful feelings and manifestations of envy and jealousy are known to work positive injury to the nervous system as well as the disposition, while *brooding* over real or imaginary wrongs has caused many cases of insanity. On the other hand, cheerfulness, contentment, patience, and manifestations of good will and good fellowship are necessary conditions for healthful nervous action.

What We Eat and Drink has an important effect upon the nervous system. Like other portions of the body, it fares best when there is a liberal supply of wholesome, well-cooked food. In addi-

tion to the usual foods there is a large number of substances which, because of the delicacy of its structure, have an injurious effect upon the nervous system. Some of these act as violent poisons while others are more mild in their action. Two classes of these substances require special consideration.

Stimulants and Narcotics.

Stimulants act upon the nervous system to *increase* its activity while the general effect of narcotics is to *lessen* its activity. Although the use of these drugs in disease may be beneficial and often invaluable, the frequent use of them in health is decidedly injurious. Among some of the more common ones may be named *alcohol*, *morphia*, the *nicotine* of tobacco, the caffeine of coffee, and the theine of tea.

Alcohol is the intoxicating principle in the usual saloon drinks, such as whisky, beer, ale, wine, etc. It is formed by the fermentation of fruits and grains. When pure it is a colorless liquid, lighter than water, with an agreeable odor and a hot, pungent taste. It is inflammable, and burns with a clear, hot flame. It is able to dissolve many substances not soluble in water, such as oils, gums, and resins. It has a strong affinity for water and is able to absorb it from organic substances. Its first effect upon the nervous system is that of a stimulant, though in large doses it acts as a narcotic.

Experiments. 1. Place a tablespoonful of alcohol in a saucer and ignite it with a burning match. Observe that the flame contains no soot and gives little light but great heat.

2. Pour some alcohol over the white of a raw egg and observe the effect. The coagulation of the albumen is due to the absorption of water from it by the alcohol.

3. Place a drop of blood on a glass slide and place over it a cover glass. Examine under a compound microscope. Then add a tiny drop of alcohol to the blood on the slide and examine a second time. The shrunken condition of the corpuscles is caused by the alcohol coagulating the albumen in them.

Give results and

inferences.

Alcohol has some very important uses. It is used as a combustible for obtaining a hot, smokeless flame. It is used in dissolving gums, oils, and resins; for medical purposes; and in the arts. It is used by scientists in preventing the decay of animal and vegetable substances and, by some physicians, in the treatment of diseases where a stimulant is needed.

The Evil Effects of Alcohol lie in its use as a beverage. It has been proven to be a poison, whether used in large or small quantities, and is in no sense to be regarded as food. Introduced into the body, it weakens the nervous system by making it too active; it hardens the tissues by absorbing water from them; it interferes with digestion and the natural circulation of the blood; it so disturbs the action of the brain as to induce *temporary insanity*, or drunkenness, which, if frequently repeated, leads to permanent insanity; it rapidly weakens the stomach, liver, and kidneys, rendering them unfit for their important work. But, worst of all, *it creates an appetite for itself* that causes the victim to take it in larger and larger doses until death or insanity is the result. As a beverage, alcohol, in all its forms, should be carefully avoided. It should never be used as a medicine except by the advice of a physician.

Morphia is perhaps the most powerful and dangerous of the narcotics. It is an extract from opium and is a valuable medicine. Its use, however, is attended with great danger, as the opium habit is easily contracted and is even worse in its effects than the alcohol habit.

Nicotine is an oily, colorless liquid obtained from tobacco. It is eminently a poison. Taken in very small quantities it is a mild stimulant, and if the doses are repeated a habit is formed which is very hard to break. Tobacco is used for the peculiar stimulating effects of this drug. The tobacco habit, while not so serious in its results as the alcohol and morphine habits, is of no benefit, is a great and useless expense, and, in many instances, causes a derangement of the healthy actions of the body. Its use by the young is especially injurious, as it decidedly interferes with the proper development of both body and mind. To the bad effects of the nicotine

may also be added those of questionable substances used either for their agreeable flavor or for adulteration.

The cigarette is as yet the most dangerous of the manufactured products of tobacco, as it has its chief consumers among small boys. In addition to the dwarfing and stunting effects which it has upon the young, it has been the direct cause of a large number of deaths in the last few years. The title "little coffin nail" is well deserved.

The Caffeine of coffee and **Theine** of tea are mild stimulants, and it is for the effects of these drugs that tea and coffee are so extensively used. Tea and coffee are similar in their action, though they affect persons differently. If the system needs a stimulant they are preferable to alcohol. Their habitual use, however, interferes with the healthy action of the body and for that reason they should be avoided.

The practice of some students of drinking coffee and tea in order to study late at night, if persisted in, can only end in nervous derangement.

References. On care of the nervous system, S., 277-281. On the effects of alcohol, F. and S., 156; S., 283-293; C., 274; J., 289. On effects of tobacco, J., 291; C., 191. On effects of tea and coffee, S., 252; C., 174. On the cigarette, S., 233. On patent medicines, S., 251.

Practical Questions. 1. Why is nervous tissue more easily injured than the other tissues of the body? 2. Of what value is sleep to the nervous system? 3. What is the special value of physical exercise to the brain worker? 4. How do fretting and worrying lessen one's power to work? 5. What mental states are conducive to the healthfulness of the nervous system? What ones interfere with its healthy action? 6. How do stimulants differ from narcotics? How do both differ from foods? 7. Give the properties and uses of alcohol. 8. What are a few of the bad effects which it has upon the body? 9. What bad effects has nicotine upon the body? 10. Why do brain workers experience worse effects from the use of stimulants and narcotics than others? 11. Show the folly of acquiring a habit injurious to the health.

APPENDIX.

To Prepare Oxygen. Mix thoroughly a heaping teaspoonful of potassium chlorate with half as much manganese dioxid and place in a test tube six inches long. The top of the tube should be tightly closed with a cork through which passes the end of a small glass tube 15 inches in length. To secure the proper shape for passing the gas into receivers, this tube should be bent nearly at right angles about an inch above the cork and again slightly, about one-half an inch from the other end.

For collecting the gas a wash basin and several large-mouthed bottles are required. Fill each bottle even full of water, place a stiff piece of paper over the mouth, and invert without spilling in the pan, which should contain water to the depth of three-fourths of an inch.

When everything is ready heat the test tube over the flame of an alcohol lamp, bringing it near enough for the flame to spread over the end of the tube. When the gas begins to pass off insert the end of the tube under one of the bottles. Leave the bottles of gas inverted in the pan until ready to use the gas. On removing keep the bottles tightly covered.

Injection of the Arteries. Remove the front portion of the thorax, exposing the heart and the lungs. Grasping the heart between two fingers and the thumb of the left hand, make an incision in the lower end of the left ventricle. Insert the end of a small tube, connected with a syringe already filled with the injecting mass, and push it well into the entrance of the aorta. Secure in this position by a ligature around the upper portion of the heart. After a good connection has been made force the injecting mass by steady pressure into the arteries. (For composition of injection masses see J., 102 and C., 66.)

To Destroy the Brain of a Frog. For certain experiments in which live frogs are used the most successful as well as the most humane way of managing them is to destroy the brain. This puts the frog under the complete control of the operator and at the same time destroys all sensation.

Make an incision with a sharp knife over the spinal cord where the head joins the body. Insert the blunted end of a wire, or a large knitting needle, and push it into the cavity occupied by the brain. Probe with the wire in different directions until sure that the different ganglia have been disorganized. When the frog drops into a relaxed and lifeless condition the operation is complete.

Collection of Blood. If only a drop or two is needed it can easily be obtained from the finger. Wrap one of the fingers of the left hand with a handkerchief, from the hand down to the last joint. Bend this joint, give it a sharp, quick blow with the point of a clean pin or needle above the root of the nail. Pressure applied to the under side of the finger will force plenty of blood out through a very small opening.

If blood is needed in large quantities it can be obtained from the slaughter house. To be sure of securing the specimens of blood needed for the experiments in Chapter II, take to the butcher three suitable vessels, upon which paste labels like the following:

1.	2.	3.
* * Fill $\frac{2}{3}$ full. While the blood is cooling, stir rapidly with the hand or a bunch of switches to remove clot. * ..... *	..... * Fill $\frac{2}{3}$ full and set aside without shaking or stirring. ..... *	..... * Fill $\frac{2}{3}$ full and thoroughly mix with the liquid in the bottle. *

Label No. 3 must be pasted on a bottle, having a tight fitting cork, which is filled one-fifth full of a saturated solution of Epsom salts.

Lime Water is prepared by dissolving lime in water. Fill a quart jar nearly full of water and add a few small lumps of *fresh* lime. Mix the two and let stand till all the undissolved lime settles to the bottom. This will require a day or more. Pour off and use the clear liquid above the lime. (Only fresh lime can be used in preparing lime water.)

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